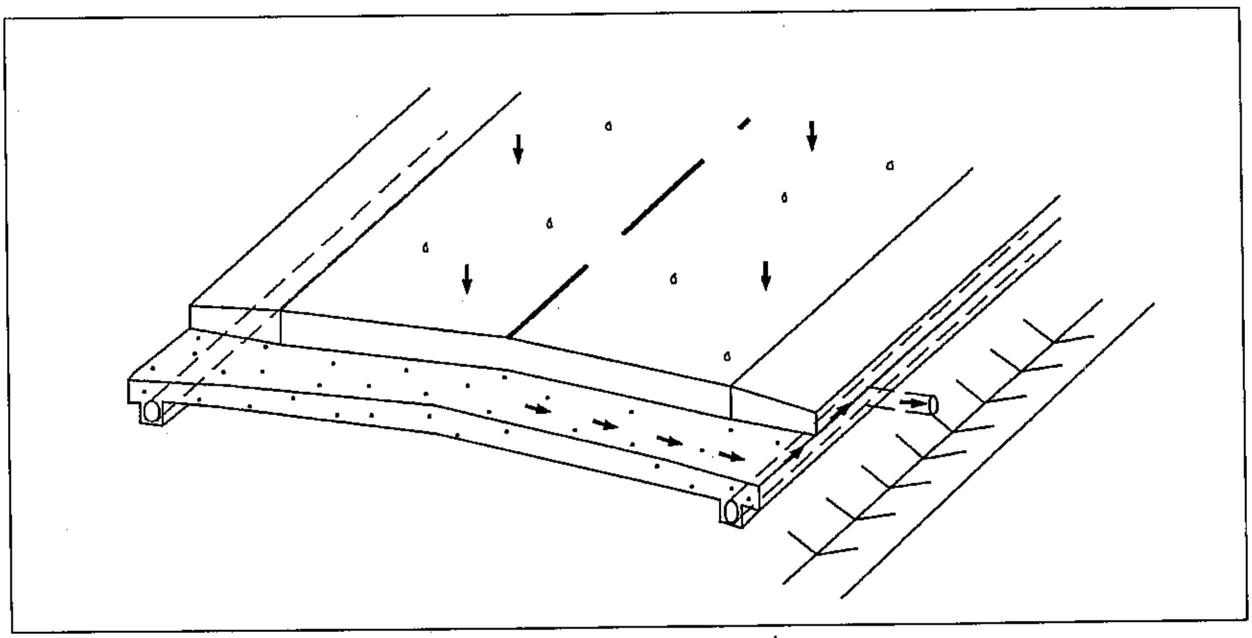
Design and Construction of Open-Graded Base Courses



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16. Abstract

For the past four years, the Illinois Department of Transportation (IDOT) has conducted extensive research into the practical application of drainable bases in Illinois. IDOT has examined readily available aggregate gradations, bonding agents, and equipment for constructing drainable bases. As the preliminary results of this research became available, IDOT built two experimental projects, with a total of seven different cross-sections. From this experience, IDOT revised both the mix and construction specifications. To guarantee an accurate evaluation of the revised specifications, IDOT constructed two demonstration projects.

The experimental projects have been monitored with underdrain outflow meters, pressure transducers and deflection testing to indicate how each of the seven cross sections are performing. The results of the performance evaluation show that drainable bases are a viable alternative to rigid bases in Illinois. As long-term performance data becomes available and as more pavements with drainable bases are constructed in Illinois, the evaluation of drainable bases will continue.

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DESIGN AND CONSTRUCTION OF OPEN-GRADED BASE COURSES

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DISCLAIMER

TABLE OF CONTENTS

EXECUTIVE SUMMARY

It is a well established fact that one of the most detrimental distresses in pavements today is pumping. Pumping occurs when free water exists between the subbase and pavement surface. As wheel loads pass over cracks and joints, the resulting slab movement can accelerate the erosion of subgrade fines. Since it is impossible to maintain water-tight pavements, the pavement designer must design a system to remove water which does infiltrate the pavement. This system is commonly referred to as a positive drainage system, and employs a drainable base, filter layer and an underdrain system to remove water which infiltrates the pavement surface.

For the past four years, the Illinois Department of Transportation (IDOT) has conducted extensive research into the practical application of drainable bases in Illinois. We have examined readily available aggregate gradations, bonding agents, and equipment for constructing drainable bases. As the preliminary results of this research became available, we constructed two experimental projects and two demonstration projects to test the practicality of our results. This report details IDOT's experience in constructing and monitoring these projects.

To assist in the evaluation, the two experimental projects have been monitored with underdrain outflow meters, pressure transducers and deflection testing. The results of the early construction and performance evaluations indicate that drainable bases are a viable alternative in Illinois. As long-term performance data becomes available and as more pavements with drainable bases are constructed in Illinois, the evaluation of drainable bases will continue. Now that the practicality of drainable bases has been determined, efforts can be concentrated on developing the most efficient and cost effective cross section.

INTRODUCTION

Water, which has infiltrated a pavement structure, is a primary cause of pavement distress. Free water in the subbase and subgrade weakens the pavement by severely limiting the pavement's structural capacity. When free water exists between the pavement slab and subbase, an approaching wheel load causes the trailing edge of the slab to deflect downward, forcing a wave of water forward. As the wheel load passes over the joint or crack, the trailing slab rebounds, and the edge of the lead slab is deflected down. This series of actions results in the erosion of material from under the edges of the lead slab, the ejection of water from joints or cracks, and the deposit of material under the trailing edge of the approach slab. This entire process is commonly referred to as pumping. Should pumping continue for any extended period of time, faulting may occur, or the pavement may crack due to the lack of adequate structural support (1). Thus, the prevention of saturated pavement conditions must be a fundamental component of good pavement performance.

In order to minimize the occurrence of saturated pavement conditions, all pavement joints should be sealed to reduce the amount of water which infiltrates the pavement structure. While a pavement slab cannot be completely sealed, properly sealed joints can significantly reduce the amount of water entering a pavement structure (2,3). In addition to sealing all joints and cracks, a good pavement design will include a positive drainage system for water which infiltrates the pavement structure.

A positive drainage system has three primary components; a drainage layer, a filter/separation layer, and a longitudinal edge drain system. The function of the drainage layer is to provide rapid drainage of free water which infiltrates the pavement structure. The filter/separation layer is used to prevent subgrade fines from infiltrating and clogging the drainage layer. The longitudinal edge drain system conveys the free water, collected by the drainage layer, out of the pavement structure. Since the early 1970's, the Illinois Department of Transportation (IDOT) has been installing longitudinal edge drain systems in most major new construction projects, and retrofitting existing pavements with an edge drain system when they are under rehabilitation. The inclusion of a drainage layer, however, did not receive serious consideration until the late 1980's.

This report describes the IDOT experience in developing specifications, cross sections and construction techniques for drainage layers. Drainable base, permeable base, open-graded base and drainage layer are all terms for the same pavement component. To alleviate confusion, the terms open-graded drainage layer (OGDL) or drainage layer will be used in this report.

HISTORICAL PERSPECTIVE

As early as 1960, pavement cross sections with drainage layers have been proposed to provide for positive drainage in pavements. These early proposals were perceived to have excessive initial costs and to be difficult to construct. Thus, they failed to generate a great deal of interest. The first field trial of a drainage layer did not occur until 1967, when an asphalt treated drainage layer was incorporated into the reconstruction of a portion of a logging road in Humboldt County, California (4). The early success of this project stimulated a slow developing interest in drainage layers, which has gradually grown into a major research effort in many states.

In July 1988, IDOT initiated a study, in conjunction with the University of Illinois, to identify and quantify the parameters which affect the hydraulic conductivity and stability of in-place open-graded drainage layer materials. This study also focused on evaluating materials available to IDOT for the construction of open-graded drainage layers, which would provide adequate support during construction. The results of this study were published in 1991 (5).

In conjunction with the research efforts at the University of Illinois, IDOT conducted a parallel study on the practical use of drainage layers in Illinois. Before a statewide standard could be developed, material gradations and pavement cross sections had to be determined. The materials used in the cross section must be readily available and at a reasonable cost, while still performing their primary drainage function. The cross section must be one which could be easily constructed with a minimal impact on pavement smoothness.

PRELIMINARY INVESTIGATIONS

Literature Review

As the preliminary results of the University of Illinois study became available, it was clear that drainage layers had the potential to substantially improve the performance of pavements. IDOT decided to extend the investigation of drainage layers by reviewing the uses of drainage layers in other states and the application of their experience to Illinois materials.

Information on both stabilized and unstabilized drainage layers was available from several states. One item common to nearly all of the states using drainage layers was the use of the AASHTO number 57 gradation or one similar to it in stabilized drainage layer mixes. Initially, IDOT decided to pursue the utilization of stabilized drainage layers because the IDOT CA-7 and CA-11 gradations are close to the AASHTO number 57 gradation. These gradations are included in Table 1. IDOT did not pursue unstabilized drainage layers because there was concern that an unstabilized drainage layer would not have adequate stability to support a paving operation. For the early field trials of drainage layers, IDOT decided to take the conservative approach and use stabilized drainage layers.

With the focus on stabilized drainage layers and the aggregate gradations selected, it was necessary to determine the content of binding agent required to adequately stabilize the drainage layer mixtures. Most states were using between 2-3 percent asphalt cement with gradations similar to the CA-7 and CA-11 gradations and experiencing no significant problems during construction. The portland cement content varied, however, depending on the water-cement ratio and the aggregate gradation. Before any field trials could be conducted, it was clear a mix design would have to be determined in the laboratory.

Laboratory Investigations

Personnel at Cal Trans recommended starting with a water-cement ratio of 0.37 and approximately 282 pounds of portland cement per cubic yard. Only top quality aggregate, which was resistant to freeze/thaw degradation, was used. Cylinders from the trial mix were made and cured. Some of the cylinders were tested for compressive strength, some were tested for permeability, and some were placed in the IDOT's freeze/thaw chamber.

The compressive strength tests averaged 894 psi for a 2 day break, 1080 psi for a 5 day break and 1391 psi for a 7 day break. These compressive strengths are as good as most of the lean concrete subbase strengths, of common use in Illinois. In addition to compressive strength testing, beams were also formed and cured for flexural testing. IDOT uses a center point loading instead of a third point loading for flexural tests. The average 2 day flexural strength was 250 psi, the 5 day average was 272 psi and the 7 day average was 250 psi.

A very simple test was used to estimate the lateral flow characteristics of the portland cement stabilized drainage layer mix. A preset amount of water was poured into the top of the drainable cylinder. The time for all of the water to drain through the cylinder was recorded, and a rough permeability coefficient was determined by dividing the height of the cylinder by the drain time. The University of Illinois was conducting extensive permeability tests on several types of drainage layer mixes; therefore, a more accurate test was not necessary (5).

The remaining cylinders were placed in the freeze/thaw chamber for testing. After 25 freeze/thaw cycles, the rocks on the top of the cylinders were beginning to become loose and some dust was starting to appear on the cylinders. After 47 cycles, the lower portion of the cylinders were starting to fall apart and the test was discontinued. Although the cylinders did not perform well in the freeze/thaw test, further consideration reveals this may be of minor significance. As long as the drainage layer is adequately consolidated and the entire system is contained within the pavement structure, the loss of the bonding agent may not be important. At no time did the aggregate itself break apart in the freeze-thaw chamber.

Several other questions were also answered from the laboratory tests. In the beginning, there was concern the concrete yield would notably decrease with a porous subbase surface. To address this concern, some of the cylinders in the lab were topped with 4 inches of portland cement concrete. From these cylinders, it was apparent that the impact of the drainage layer on the concrete yield would be minimal.

In addition, there were also concerns about the basis of payment for the pavement surface. In Illinois, the pavement surface thickness is usually determined by cores collected from the completed pavement. The porous subbase surface might make defining the line between the pavement surface and the subbase difficult. The same cylinders, which were made to determine the affect of the drainage layer on the yield, also showed that the line between the pavement surface and the drainage layer was well defined.

Construction Specification

With the type of drainage layer defined and the laboratory testing complete, a construction specification was required before an experimental project could be built. Due to the fact that the portland cement stabilized mix design was similar to the mixes used in California, the construction specification for the portland cement and asphalt cement drainage layers were also similar to those used in California.

Both types of drainage layers were to be placed with a standard paver and rolled once, without vibration, to "seat" the aggregate. The roller was to be a tandem steel wheel roller. There were no density requirements placed on either the asphalt or portland cement treated drainage layers, as it is not considered to be a structural member of the pavement. Also, the portland cement stabilized drainage layer was to be cured starting 24 hours after placement. Trimming the in-place drainage layer was not required nor allowed, but the removal and replacement of any drainage layer section which had been contaminated was required.

EXPERIMENTAL PROJECTS

Bloomington Test Sections

Cross Sections

The first highway project in Illinois with an OGDL test section was built in August of 1989, approximately three miles north of Bloomington as part of FA 412 (I-39), Section 57-2 in McLean County. The location of this project is shown in Figure 1.

The typical cross section for this project consists of a 10.75-inch hinge jointed PCC pavement, which was placed on a 4-inch lean concrete subbase (CAM II). The subgrade was lime modified to a depth of 16 inches under the entire project. Geocomposite underdrains were placed at the shoulder/mainline joint with outlets every 500 feet. Tied concrete shoulders were included in the cross section with joints matching the hinge and dowel joints in the mainline pavement. All of the dowel and hinge joints were sealed, but the shoulder/mainline joint was not sealed. The typical cross section for this pavement is included in Figure 2.

The portland cement treated OGDL test section is 1250 feet long and is located at the north end of the project in the northbound lanes only. The open-graded drainage layer is 6 inches thick, 2 inches thicker than the lean concrete base. A 6-inch thick drainage layer was used to address concerns that a thinner layer would not provide adequate support for paving operations. The OGDL extends 18 inches out under the shoulder. The rest of the cross section details are identical to those of the standard cross section. The OGDL cross section is also shown in Figure 2.

Mixture Characteristics

The OGDL mix consisted of a crushed limestone aggregate which met the IDOT CA-07 gradation specification (nominal top size of 1.5 inches). The CA-07 aggregate also met the IDOT Class A quality specification (6). The mixture was prepared in a concrete plant and contained 282 pounds per cubic yard of portland cement. A water-cement ratio close to 0.37 was used.

The control section has a CAM II subbase. This subbase contains coarse aggregate, fine aggregate and a minimum of 200 pounds of portland cement per cubic yard. The entrained air was between 7-10 percent and the required slump was 1-3 inches.

Construction

The CAM II subbase was placed with the Rex Town and Country concrete paver shown in Figure 3 and in accordance with standard practices in Illinois at that time. The OGDL was placed with the same concrete paver as the CAM II subbase; however, the paver had significant difficulties in spreading and placing the mixture. The OGDL mixture did not "flow" as fresh concrete will, and the concrete paver could not "push" the mixture. After several delays due to equipment problems, a front end loader was used to spread the mixture out, and the concrete paver was used to bring the mixture to grade. The original test section was to be 1500 feet long, but continuous equipment problems required discontinuing construction after 1250 feet. Throughout the day, adjustments were made to the mixing time to ensure the aggregate was well coated with portland cement. Figure 4 shows good coating with a 75 second mix time.

Immediately after the mixture had been placed, a 2-axle, 9-ton steel-wheeled roller made two passes over the drainage layer to "seat" the aggregate. The drainage layer had crease lines at the edges of the roller pattern. To address this problem, the breakdown rolling was done with the drive wheel forward and the tiller in back; however, Figure 5 shows that this was not entirely effective. In addition to leaving crease lines, the roller was "knocking" the edge of the drainage layer over, as shown in Figure 6. Although minor adjustments to the mix time appeared to alleviate some of the rolling problems, the finished surface was very uneven and rough. Once the drainage layer was placed, it was sprayed with a fine mist of water and covered with plastic to cure. Figure 7 is a photograph of the curing process. After the mainline surface was placed, the geotextile underdrains were installed. The underdrains were placed in a continuous operation without any problems.

In Illinois, the contractor is allowed to use the surface of the subbase as grade control for the pavement surface. Due to extensive equipment problems experienced while placing the drainage layer and uneven rolling, the rough surface of the drainage layer may have lead to a rough pavement surface; however, continued paving equipment breakdowns during the placement of the surface added to the roughness problems. The pavement surface was ground more than usual to meet construction smoothness criteria.

LaSalle/Peru Test Sections

Cross Sections

The second experimental open-graded drainage layer project was built in August of 1990, approximately ten miles south of LaSalle/Peru as part of FA 412 (I-39), Section 50-1, 2, 3 and 50-(1, 2, 3)SG in LaSalle County. The test sections are located just north of the IL 18 interchange. The location of this project is shown in Figure 1.

The typical cross section for the control test section consisted of a 10-inch continuously reinforced concrete pavement (CRCP), which was placed on a 4-inch lean concrete subbase (CAM II). The subgrade was lime modified to a depth of 16 inches. Plastic pipe underdrains were placed at the shoulder/mainline joint with outlets every 500 feet. The underdrain trench was 30 inches deep, 8 inches wide and backfilled with a sand which met the IDOT FA-01 or FA-02 specification (6). Tied concrete shoulders were incorporated into the cross section, and the shoulder/mainline joint was sealed. The typical cross section for this pavement is included in Figure 8.

This experimental project consists of six different test sections and a CAM II control section. The six test sections consisted of three different cross sections stabilized with asphalt cement on the northbound side and portland cement on the southbound side. The three cross sections included a 4-inch OGDL placed on the lime modified subgrade, a 5-inch OGDL placed on the lime modified subgrade and a 4-inch OGDL placed on a 3-inch dense aggregate filter layer, which was placed on the lime modified subgrade. The two different drainage layer thicknesses and the filter layer were used to try to quantify what affect these parameters had on the performance of the drainage layer. Figure 9 shows the layout of these test sections.

In each of the test sections, but not the control section, the longitudinal underdrains were moved from the shoulder/mainline joint to one foot in from the outside edge of the shoulder. They were not placed directly at the outside edge of the shoulder in order to minimize the potential for contamination. The drainage layer was extended out under the shoulders to prevent differential frost movement from unlike materials. The top of the underdrain trench was covered with a geotextile fabric to prevent the sand from infiltrating the drainage layer. The typical cross sections for these test sections are included in Figure 8.

Mixture Characteristics

All of the OGDL mixes consisted of a crushed limestone aggregate which met the IDOT CA-07 gradation specification. The CA-07 aggregate also met the IDOT Class A quality specification (6). The portland cement mixture was prepared in a concrete plant and contained 282 pounds per cubic yard of portland cement. A water-cement ratio close to 0.37 was used.

The asphalt cement treated OGDL mixture was prepared in a batch asphalt concrete plant and transported to the project. Great difficulty was encountered in attempting to attain temperatures high enough for thorough mixing. Standard bituminous mixes contain fine aggregate, which help control mixing temperatures. The asphalt cement treated OGDL mix had virtually no fine aggregate. This problem was not fully addressed during construction, but did not appear to affect the quality of the final drainage layer. The asphalt content was between 2 and 3 percent.

Construction

Figure 10 is a photograph of attempting to place the portland cement treated drainage layers with a CMI concrete paver. Since this paver was larger than the paver used to place the Bloomington test section, it was believed it would handle the placement of the portland cement treated drainage layer mix better. Again, this method of placement did not work and a front end loader was brought in to spread the mix out as shown in Figure 11. A 12 foot wide asphalt concrete paver was used to place the rest of the portland cement treated drainage layer mix. Directly after the mixture had been placed, a 2-axle, steel-wheeled light weight roller made two passes over the drainage layer to "seat" the aggregate. The portland cement treated drainage layer was cured for one day with a fine mist of water after placement.

Although the asphalt cement treated drainage layer mix had to be transported to the job, there were no problems with drain down in the haul trucks. The asphalt treated drainage layers were placed in two 12 foot passes with an asphalt concrete paver. This is the same paver used to place the portland cement treated drainage layer and is shown in Figure 12. After the mixture had been placed, a 2-axle, steel-tired light weight roller made two passes over the drainage layer to "seat" the aggregate.

As with the Bloomington test sections, most of the surface in the LaSalle/Peru test sections did not meet the construction smoothness criteria and had to be diamond ground.

Instrumentation

As part of the performance monitoring evaluation of open-graded drainage layers, flowmeters were installed at selected underdrain outlet locations in each of the test and control sections. The flowmeter system consists of a calibrated tipping bucket and a battery powered electronic data recording system. As water drains from the underdrain system, it fills half of the tipping bucket. When one side of the bucket fills to a preset level, the bucket pivots around a center point. As the bucket pivots, the full side is emptied, and water is collected in the opposite side. The data recording equipment records the number of tips per a preset time interval in ASCII files. The tipping bucket design is shown in Figure 13. At each of the experimental pavements, a rain gauge was also installed and connected to the data recording equipment.

Two pressure transducers were installed in the LaSalle/Peru experimental project. A pressure transducer is a thin membrane, which has a strain gauge in the center of it. As the pressure head over the pressure transducer changes, the strain gauge measures this change in feet of pressure. The pressure transducers indicate the extent of pore pressure in the pavement structure. Pumping may occur when the pore pressure is allowed to build up to the pavement slab.

When the construction of the test sections was completed, the locations of the pressure transducers were selected. One transducer was placed in the control section and the other in the 4-inch cement treated drainage layer on the 3-inch filter layer. The transducers were placed in the outer wheelpath, approximately 18 inches from the shoulder/mainline joint and 4 feet below the top of the pavement. Cores were taken at these locations and the subgrade material was augered out. The pressure transducers were installed as shown in Figure 14. The pressure transducers were connected to the outflow meter recording equipment, with pressure readings recorded along with the outflow data in ASCII files.

PERFORMANCE MONITORING

Deflection Data

Bloomington Test Sections

In 1991 and 1992, the Bloomington test sections were tested with IDOT's Dynatest 8002 Falling Weight Deflectometer (FWD). The FWD was used to make a series of drops of 4,000, 8,000 and 12,000 pounds in both the control and OGDL test sections. These drops were normalized to a standard 9,000-pound load during analysis. Data were collected from tests conducted on the corners, on the edge, and in the center of the pavement panels. Figure 15 is a diagram depicting the FWD test locations. All of the equations used to calculate the results of the FWD tests, are included in Table 2. The test data collected from the corner tests were used to determine the load transfer efficiency (LTE) of the joints and LTE of the tied PCC shoulders. The results of these tests are included in Tables 3, 4A, and 4B. The data collected to date are baseline data. A detailed analysis will not be appropriate until some future date; however, the data do indicate better LTEs at the hinge joints than the dowel joints. In addition, these baseline data do not indicate a significant difference in the performance of the control and OGDL test sections.

With the addition of a fifth sensor, data indicating the LTEs of the tied concrete shoulders were also recorded during the corner tests. The shoulder LTEs are susceptible to wide fluctuations in values, as tests over tie bars result in higher LTE values than other tests. Nonetheless, the 1992 data indicates that there is a significant difference in the performance of the shoulder LTEs of the control and OGDL test sections. The LTE for the shoulders in the OGDL sections average 20 percentage points higher than the LTE in the control test section.

The edge test data are used to calculate deflection basin areas and measure the tied PCC shoulder LTE. Deflection basin areas are an indication of a pavements structural integrity and are calculated by determining the area of the deflection basin, as shown in Figure 16. The deflection basin areas calculated from the edge tests are included in Tables 5 and 6. The 1991 and 1992 values compare favorably with conventional new PCC pavements.

Shoulder LTEs were calculated from the edge FWD test data and are included in Tables 5 and 6. The shoulder LTEs calculated from the edge test data do not indicate a wide difference in the performance between the control and the OGDL test sections. The shoulder LTEs from the edge tests are higher than the corner tests because the joint LTEs will have an indeterminable affect on the shoulder LTEs.

The center panel test data was used to calculate deflection basin areas and subgrade modulous (E_{Ri}) values. The results of the center panel tests are included in Tables 7 and 8. As discussed earlier, the deflection basin areas are indications of the structural integrity of the pavement. The average area values for 1991 and 1992 indicate both the control and test sections have good structural integrity. The E_{Ri} values indicate the structural integrity of the subgrade. The values calculated from the center panel tests indicate good structural support.

LaSalle/Peru Test Sections

In 1991 and 1992, the LaSalle/Peru test sections were also tested with IDOT's Dynatest 8002 Falling Weight Deflectometer (FWD). The same field procedures used on the Bloomington test sections were followed when testing these test sections, but no corner tests were conducted as this is a CRC pavement. The results of the data collected during the edge tests are included in Tables 9, 10, 11, and 12. The load transfer shown in these tables is the LTE across the cracks in the CRC pavement. As this is a new CRC pavement, these values are very high, ranging in the lower to middle 90 percentile. In conjunction with the high crack LTEs, the shoulder LTEs are also very high. These values compare favorably with those of newly constructed CRC pavements.

The center panel tests are used to calculate the deflection basin areas and the subgrade modulous (E_{Ri}). The results of these tests are included in Tables 13 through 16. Few tests were conducted in the center of the panel; therefore, averages were not calculated. Nonetheless, these baseline data indicate the test sections are as structurally sound as new CRC pavements. Although the data is limited, the results indicate structural integrity is good at this time. One of the concerns with using a dense graded base as a filter layer is that the dense graded base will hold water and therefore weaken the subgrade. The deflection data does not presently indicate a substantially lower E_{Ri} for the test sections with filter layers; however, as more data becomes available, this will be investigated in more detail.

Tipping Bucket Data

Bloomington Test Sections

For over two years, tipping bucket data have been collected from the Bloomington test sections. All of this data is stored in a database and graphed by rainfall. The amount of data collected to date is quite extensive. Although informative on general trends, it would be beyond the scope of this report to analyze every rainfall recorded. To simplify the analysis, only single event rainfalls were analyzed. A single event rainfall is one in which all of the rainfall occurs in the same time interval; the rain does not stop and start at a later time. In order for a rainfall to qualify as a single event rainfall, the underdrain outflows must have reached a point of minimal flow prior to the next rainfall. The arbitrary point of 0.5 gallons per 10 minute interval for 30 minutes was chosen as the point of minimal outflow.

By using this selection criteria, seven rainfalls qualified for analysis from the Bloomington test sections. On this experimental project, the rain gauge is in the control section. As discussed previously, the OGDL test section is on the northbound side of the highway, and the control section is in the southbound lanes, parallel to the OGDL test section.

The first parameter investigated from the tipping bucket data was the relationship between the total rainfall and the total outflow. The averages of these data are presented in Table 17. To assist in visualizing the relationship between these variables, they were graphed with a best-fit line in Figure 17. From Table 17, the coefficients of determination (R^2) are 0.53 for the control section and 0.48 for the OGDL test section. These coefficients of determination are low and indicate that there is not a good relationship between the two variables.

In conjunction with this relationship, a comparison of the total outflow to the total possible outflow was conducted. The total possible outflow was calculated by multiplying the lane width by the underdrain outlet spacing by the volume of rainfall recorded. The volume of the actual outflow was then divided by the total possible volume (assuming 100 percent infiltration) and multiplied by 100. The results of this analysis are included in Table 18. The results indicate outflow rates of seven and twelve percent.

The second parameter investigated was the total drain time for the test and control sections. The averages of these data are presented in Table 19. For the low volume rainfalls, the control section takes longer to drain than the OGDL; however, this relationship is reversed for rainfalls greater than 0.45 inches. When considered in conjunction with the total outflows for the sections, it is clear that the control section drains slightly more water in less time than the OGDL for the higher volumes of rainfall. This relationship is the exact opposite from what was anticipated. By increasing the flow characteristics of the base course, the volume of water drained should increase and the drain time should decrease. This phenomenon will be investigated in more detail later in this report.

The final parameter evaluated was the time for the peak outflow to occur in each section. Table 20 contains a comparison of the volume of rainfall at which the peak outflow occurred and the peak outflow volume. Although the control section usually peaks at a lower rainfall volume and a higher outflow volume for a given rainfall, there is no significant difference between the sections at this time.

LaSalle/Peru Test Sections

As with the Bloomington test sections, only single event rainfall data were analyzed for the LaSalle/Peru sections. For these sections, eleven single event rainfalls have been recorded. Due to equipment problems, some data may be missing for some of the rainfalls in the various test sections. In addition, it was extremely difficult to distinguish minimal outflows for the control section as it almost always flowed between 0.5 to 1.0 gallons per 10 minute time interval. When there was any question on the validity of any of the data, it was not included in this analysis.

The data for the total outflow for the portland cement treated drainage layer test sections are included in Table 21 and Table 22 for the asphalt treated OGDL sections. The coefficients of determination are also indicated in Tables 21 and 22. With the exception of the control section, the coefficients of determination are very high. Coefficients of determination 0.80 or better indicate a good relationship between the two variables.

Figures 18 and 19 are graphical comparisons with best fit lines of these relationships. The recorded outflows from all of the test sections are significantly higher than the control section. This in part can be related back to the placement of underdrains. In the OGDL test sections, the underdrain was moved to the outside edge of the shoulder. In the control section, the underdrain was left at the shoulder/mainline joint.

Since the outflow volumes increase with the underdrains placed at the outside edge of the pavement, it is possible that some of the water which flows across the pavement and shoulder, is "backflowing" into the underdrain system. This theory is supported by the data presented in Tables 23 and 24. Considering only the 12-foot lane when calculating the volume of total possible outflow, shows that there are several instances when the outflow rate is more than 100 percent. If the shoulder volume is added to the lane volume, the percent infiltration decreases with only one instance of an actual outflow greater than the possible outflow. These data are included in Tables 25 and 26.

In addition to the potential for rainfall to "backflow" into the underdrain system, there is another possible explanation for the large underdrain outflow volumes. Each of the test sections are 1000 feet long, with underdrain outlets every 500 feet. A tipping bucket was installed at one outlet and the other outlet was left open. A recent field inspection of all of the outlets revealed that most of the open outlets were 30-70 percent clogged. If the open outlets are clogged to a significant level, the underdrain outflow will carry on down to the tipping bucket outlet. The only open outlet which was not clogged was the open outlet in the 5-inch asphalt cement treated test section. This is the section with the lowest outflow.

It is interesting to note that the coefficient of determination for the LaSalle/Peru control section and the Bloomington test and control sections are within close proximity of each other. In the Bloomington sections, the underdrain was a geocomposite mat drain placed at the shoulder/mainline joint. When the data for the Bloomington test section is graphed on the same scale as the LaSalle/Peru section, as shown in Figure 20, the OGDL test section and the control section almost mirror the control section in the LaSalle/Peru experimental project. Perhaps this is due to the placement of the underdrains and perhaps it is also due to the type of underdrain used. Further study would be required to determine the exact cause of the drastic difference in underdrain outflows.

The second parameter investigated from the tipping bucket data was the relationship between the total drain time and the total rainfall. These data are presented in Tables 27 and 28 for the portland and asphalt cement treated OGDLs respectively. The 5-inch asphalt treated OGDL flows the least amount of water for the test sections, with only the control section having smaller outflow volumes. From Tables 27 and 28, it is also clear that the 4-inch OGDLs on the lime modified subgrade average faster drain times than the 4-inch OGDLs on the filter layer. By comparing this result with the values in Tables 21 and 22, it is clear that the 4-inch OGDL on the lime modified subgrade drains less water in less time than the 4-inch OGDL on the filter layer. This result is as expected because the filter layer will have more of a tendency to hold water than the lime modified subgrade.

The final parameter reviewed was the peak outflow data as shown in Tables 29 and 30. As with the Bloomington data, the total volume of rainfall when the peak outflow occurred was calculated. By reviewing the data in Tables 29 and 30, it is clear that the 4-inch OGDLs on the filter layer usually peaked at a higher volume and lower volumes of total rainfall than the 4-inch and 5-inch OGDLs on the lime modified subgrade. From this observation and the observation that the 4-inch OGDLs on the filter layer took longer to drain, it can be concluded that the filter layer will initially transport water to the underdrains efficiently. As the rainfall continues, the filter layer will become saturated and act less efficiently than the lime modified subgrade.

Pressure Transducer Data

The data collected from the pressure transducers in the LaSalle/Peru test section and control section are very informative. As previously discussed, a pressure transducer was installed in the portland cement treated 4-inch OGDL on a filter layer test section and in the control section. As shown in Figure 14, the pressure transducers were placed four feet below the top of the pavement. All pressure readings were recorded in feet of pressure head above the pressure transducer. Readings of pressures greater than 3.17 feet indicate that the pressure is in the pavement structure. Readings of 2.83 feet to 3.17 feet indicate the pressure head is located within the subbase layer. For the

OGDL test section, readings of pressures between 2.58 and 2.83 feet indicate the pressure head is located within the filter layer. Readings below 2.83 feet for the control section and 2.58 feet for the OGDL test section indicate the pressure head is located in the lime modified subgrade.

From July of 1991 to November 1992, pressure head readings were recorded every ten minutes. As the data were collected, they were stored in a database and graphed by week. Examples of these data are included in Figures 21 through 24. The top line on these graphs indicates the bottom of the pavement. The second line indicates the bottom of the separation layer. It is clear from these graphs that the pressure, with relationship to the rainfalls, responds quickly. Individual spikes in pressure increases can be seen for each peak in the rainfall. In addition, from Figures 21 and 22, it is clear that the control section allows the pressure head to build up in the pavement structure. This is extremely important because it is under these conditions that pumping will occur. The OGDL test section has never recorded a pressure reading in the pavement structure.

By November 1992, over 72,000 readings for each transducer had been recorded. For a summary analysis of all of the data, the readings were averaged into hourly readings. These readings were then graphed in histograms for the control and test sections. The data collected in 1991 and 1992 from the control section are included in Figures 25 and 26 respectively. The data collected from the OGDL test section in 1991 and 1992 are shown in Figures 27 and 28 respectively.

These histograms show the range and average reading levels over the entire period. From Figures 25 and 26, the control section usually has a pressure head of 1.6 to 2.0 feet. The maximum reading for the control section is 4.0 feet, and the minimum reading is 1.4 feet. From Figures 27 and 28, the OGDL section usually has a pressure reading 2.2 to 2.6 feet. This is higher than the control section. Most likely this higher average is due to the fact that the filter layer has a tendency to hold water. The maximum value for the test section is 3.0 feet and the minimum value is 0.2 feet. Even though the average reading for the test section is higher than the control section, the maximum and minimum readings are significantly less for the test section.

Riding Quality Data

Table 31 contains the profiler ride data for the LaSalle/Peru test sections. This data was collected in June 1991, after the job had been ground to meet the IDOT smoothness specification for new construction. This data is strictly baseline data. Analysis will be performed as long-term data becomes available.

DEMONSTRATION PROJECTS

The experience obtained from constructing the two experimental projects led to several revisions in the drainage layer cross section and construction specifications. It was clear that other projects should be constructed to ensure the revisions were applicable; therefore, IDOT decided to construct two demonstration projects. To guarantee an accurate evaluation of the revised specifications, the drainage layer in the demonstration projects extended the entire length of the selected projects.

El Paso

Cross Sections

In 1992, the first of the two demonstration projects was constructed in District 3 in Woodford County at El Paso. This project was the final phase of I-39 (FA 322), Section 102-1, 102-2, and SG. The location of this project is shown in Figure 29. The pavement cross section is a 10-inch CRCP, which was placed on a 4-inch portland cement treated drainage layer. The southern segment of the project (from Kappa to the US 24 interchange) placed the drainage layer on a 3-inch filter layer, which was placed on the 16-inch lime modified subgrade. The northern segment of the project (from US 24 to Panola) placed the drainage layer directly on the 16-inch lime modified subgrade.

The 4-inch pipe underdrains were placed 1 foot in from the outside edge of the shoulder. Outlets for the underdrains were located on 500-foot intervals. In a positive drainage system, the permeability of the materials used will increase as water is transported through the system, thus the trench backfill material was changed from the sand used in the experimental pavements to untreated OGDL aggregate in the demonstration projects. The trenches for the underdrains were lined with a geotextile fabric to prevent fines from clogging the underdrain system. The typical cross section for this project is shown in Figure 30.

Mix Characteristics

The required portland cement content was changed from 280 pounds per cubic yard to a range from 200 to 280 pounds per cubic yard. For a coarse aggregate stockpile, 200 pounds per cubic yard would be sufficient to bind the aggregate together; however, a portland cement content of 280 pounds would be required for a fine graded aggregate stockpile. In addition, the water/cement ratio was increased from 0.37 to 0.50 to increase workability. For this particular project, a cement content of 240 pounds per cubic yard and a water/cement ratio of 0.47 was used. Figure 31 shows that this combination ensured the aggregate was completely coated. As the center of the aggregate stockpile was reached, the water/cement ratio was adjusted to account for additional stockpile moisture. This type of mixture is extremely sensitive to stockpile moisture and must constantly be monitored. The "wet spot" shown in Figure 32 is a result of a change in stockpile moisture.

Construction

Instead of attempting to place the mixture with a concrete paver, the drainage layer mixture was to be placed with a mechanical concrete spreader. The spreader was required to have either a spreader box or belt placer in front. On this project, the spreader box shown in Figure 33 was used. In addition, surface pan vibrators were required to "seat" the aggregate to eliminate rolling the drainage layer, as this seemed to adversely affect the smoothness of the surface coarse. This change resulted in a smooth subbase surface, as shown in Figure 34.

On this demonstration project, the contractor elected to use an autograde with hydraulic vibrating pans attached. This method of placement worked extremely well, averaging more than a mile of 30-foot wide drainage layer placed per day. The pan vibrators were run around 4500 rpms. This "seated" the drainage layer to the degree that it could be walked upon with minimal displacement. The drainage layer was not cured.

Once the drainage layer was placed, the pavement surface was constructed. At one point, the filter layer underneath the drainage layer became saturated. When paving was attempted in this area, the outer edge of the drainage layer broke off. After allowing ample time for the filter layer to dry, paving operations were resumed.

The drainage layer appeared to have a negligible impact on yield, and the drainage layer did not adversely affect the pavement surface smoothness, as the average profilograph number for the entire project was four. With the mainline pavement in-place, the underdrains were installed, and the shoulders, with a drainage layer, were constructed.

Belleville

Cross Sections

In 1992, the construction of the second demonstration project was started in District 8 in St. Clair County near Belleville. This project consisted of rehabilitating two existing lanes of IL 161 and constructing a median and two new lanes. The location of this project is shown in Figure 29. The new pavement cross section is a 14-inch full-depth asphalt concrete pavement, which was placed on a 4-inch asphalt cement treated drainage layer. Approximately one-third of the drainage layer was placed on a 3-inch dense-graded base, the rest of the drainage layer was placed directly on the lime modified subgrade.

The 4-inch pipe underdrains were placed 1 foot in from the outside edge of the shoulder. Outlets for the underdrains were located on 250-foot intervals because there were no median underdrain outlets. The trenches for the underdrains were lined with a geotextile fabric to prevent fines from clogging the underdrain system and were backfilled with untreated drainage layer material. Typical cross sections for this project are shown in Figure 30.

Mix Characteristics

The aggregate gradation used was a CA-11 with 2-3 percent asphalt cement. The mixing temperature was lowered from 250° -350°F to 240° - 300°F.
It was felt that the revised temperature range would be hot enough for the asphalt cement to set-up but low enough to maintain an operating constant.

The minimum temperature required when the mix was placed was 200°F. Some batches, however, were only 180°F when they reached the paving operation. The aggregate in these batches was not well coated with asphalt; therefore, the maintenance of the minimum temperatures is very important.

Construction

The asphalt cement treated drainage layer was placed with the modified autograde shown in Figures 35 and 36. The autograde included a spreader box on the front and a tamping bar on the back of the autograde. After placement, the mix was rolled with a tandem, steel-wheeled roller. Some of the drainage layer was rolled with a 5-ton roller at 150°F - 200°F, and some of it was rolled with a 10-ton roller at 100°F - 150°F. Both rollers, in the specified temperature ranges, obtained approximately 0.75 inches of consolidation. The difference between the rolled and unrolled drainage layer mix can be seen in Figure 37.

Once the drainage layer was in place, the first lift of binder was placed. The hot binder mix appeared to have no affect on the drainage layer, and the drainage layer did not affect the nuclear density measurements of the binder. Due to contamination concerns, no equipment was allowed on the drainage layer after it was compacted. This included haul trucks; therefore, a material transport device was used to convey the material from the haul trucks to the paver. Some of the haul trucks were allowed to pull onto the drainage layer as part of an experiment to evaluate their impact on the drainage layer. As long as the haul truck access points were varied, they had a very minimal impact on the edge of the drainage layer and no impact in the center of the drainage layer due to turning movements.

This project should be completed in the fall of 1993.

RECOMMENDED SPECIFICATION AND CROSS SECTION

From the experience acquired through the demonstration projects, the construction specifications were revised. Copies of the recommended specifications are included in Appendix A. The asphalt cement and portland cement treated drainage layers have been combined into one specification, although they could be used as individual specifications.

The revised drainage layer specification requires the use of both a 5-ton and a 10-ton roller to "seat" the asphalt cement treated drainage layer. From the demonstration project, it was evident that a single roller could "seat" the drainage layer, but the combination of both rollers provided the most stable layer without crushing the aggregate.

The revised specification does not require the removal of the OGDL beneath the paving trackline. At first it was believed the drainage layer beneath the trackline would be contaminated and should be removed. Both demonstration projects showed that care during construction of the mainline pavement could prevent contamination of the drainage layer. The revised specification, however, does require the removal of any contaminated segment of the drainage layer.

Perhaps the most drastic revision of the specification allows the haul trucks to drive onto the drainage layer to dump material into the paver. Originally, due to the fear of crumbling the outer edges of the drainage layer, haul trucks were not allowed on the drainage layer at all. Although the drainage layer cannot be used a haul road in the revised specification, the haul trucks can pull onto the drainage layer to dump into the paver.

The final recommended cross section is indicated in Figure 30. This cross section is identical to the standard cross section recommended for and used in the demonstration projects. Typical shoulder details are included in Figures 38 and 39.

SUMMARY

Over the past five years, the Illinois Department of Transportation has thoroughly reviewed the practical applicability of open-graded drainage layers to Illinois highways. The following is a list of general statements, which are true for either asphalt cement or portland cement treated open-graded drainage layers.

- A 4-inch thick drainage layer has the necessary capacity to efficiently drain a two lane highway segment.

- The drainage layer should be placed with a large machine. The placement machine must be capable of spreading and placing a harsh mix to the required grade.

- Rigid lateral drains should be used to ensure the longitudinal drains are properly outletted.

- The same aggregate gradation, which was used in the drainage layer, should be used to backfill the longitudinal underdrain trenches. It is not necessary to stabilize this material.

- Contamination should be defined as anything that will adversely impact the efficiency and performance of the drainage layer. Any contaminated drainage layer should be replaced.

- The use of a drainable base under a full-depth asphalt concrete pavement does not appear to have an affect on the density of the first lift of binder.

- Rolling the drainage layer to seat the aggregate is not a good idea when using the drainage layer under a portland cement concrete pavement.

- When the drainage layer is used under a full-depth asphalt concrete pavements, haul trucks can be allowed to pull onto the drainage layer to dump into the asphalt paver.

- Due to the open nature of the drainage layer, curing the portland cement treated drainage layer is impractical.

In addition to these general statements, several other observations should be noted. The dense graded aggregate filter layer does retain water for extended periods of time. This is evident from both the pressure transducer data and the first demonstration project. The pressure transducer data also shows that the CAM II subbase will allow hydrostatic pressures to build up into the pavement, which can lead to pumping.

The early deflection data indicate that all of the test sections with drainage layers are structurally sound pavements. This data will be used as baseline data in future investigations. Also, the tipping bucket data reveals a solid relationship between the amount of rainfall and the amount of water collected and drained by the drainage systems. As more data becomes available, the relationships between the rainfall, drain time, and peak outflows will be investigated in more detail.

When specifically looking at the portland cement stabilized drainage layer, the best mix design for Illinois materials is a water/cement ratio of approximately 0.50, aggregate gradations of either CA-7 or CA-11, and 200-280 pounds of cement per cubic yard. The actual cement content should be determined by the gradation of the aggregate stockpile. The water/cement ratio should be adjusted as the mix is very sensitive to stockpile moisture. The drainage layer mixture is very open and dries rapidly, thus curing is not required.

For asphalt stabilized open-graded drainage layers, the mixing and placement temperatures are very important. If the temperatures are not maintained at the minimum levels, the aggregate will not be well coated, which may result in a weakened drainage layer.

RECOMMENDATIONS

There are related areas to this study that should be investigated in more detail, but were too broad to be addressed in this study. The following list summarizes areas for future investigations:

- Since the drainage layers remove the infiltrated water quickly, it may be possible to make the underdrain trench shallower, without risking frost heave problems.

- Illinois is one of only few states which lime modifies the subgrade as a standard practice. As long-term performance data becomes available, whether or not a dense graded aggregate filter layer is also needed should be investigated.

- The benefits of using drainage layers under portland cement concrete pavements have been proven in many studies; however, little information is available on the benefits of using drainage layers under full-depth asphalt concrete pavements.

- The first drainage layer test pavement in Illinois has geocomposite underdrains. This test section is not draining the volume of water other sections are. A detailed study of the performance of all drain types with drainage layers would be very informative.

- The underdrain outflows recorded on the open-graded drainage layer test sections are significantly larger than the outflows from standard subbases. The larger outflows lead to erosion problems at some of the lateral underdrain outlets. A method of controlling this erosion should be identified.

- The underdrain outflows measured by the tipping buckets indicate that the underdrains are draining all of the rainfall that falls on the pavement and the shoulder. Since the pavements being studied are new pavements, it is highly unlikely all of the rain that falls on the shoulder and the pavement is infiltrating the pavement system. A study to determine if water is running off of the shoulder and "wrapping around" the outer edge of the pavement to the underdrains should be conducted.

- Finally, a detailed study, which incorporates more than the single event rainfall tipping bucket data, might reveal more information on the performance of the individual cross sections with drainage layers.

As long-term performance data becomes available and as more pavements with drainage layers are constructed, these areas of recommended research will continue to be investigated. Now that the constructability of drainage layers has been determined, efforts can be concentrated on developing the most efficient and cost effective cross sections with drainage layers.

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TABLE 1: COARSE AGGREGATE GRADATIONS

	SIEVE SIZE PERCENT PASSING									
GRAD. NO.	1.5"	1.0"	0.75"	0.50"	0.38"	NO.4	No.8	NO. 16	NO. 50	NO. 200
CA 6	100	95+5		75+15		43+14		25+15		8+4
CA 7	100	95+5		45+15		5+5				
CA 10		100	95+5	80+15		50+10		30+15		9+4
CA 11		100	92+8	45+15		6+6		3+3		
CA 13			100	97+3	80+10	30+15		3+3		
CA 16				100	97+3	30+15		2+2		
AASHTO #57	100	95-100		25-60		0-10	0-5			

TABLE 2: EQUATIONS FOR FWD CALCULATIONS

$$\text{JOINT LTE} = (D1/DO) \times 100\%$$

$$\text{SHLDR LTE} = (D5/DO) \times 100\%$$

$$\text{AREA} = 6\left(1 + 2\frac{D1}{DO} + 2\frac{D2}{DO} + \frac{D3}{DO}\right)$$

$$\text{ERI} = 25.7 - 7.28\,(D3) + 0.53\,(D3)^2$$

TABLE 3: 1991 FWD CORNER TEST DATA FOR THE BLOOMINGTON SECTIONS

SECTION DESCRIPTION		D0 (mils)	D1 (mils)	D5 (mils)	JOINT LTE	SHLDR LTE
CONTROL		4.5	4.2	2.6	93.3	57.8
		6.4	4.2	3.8	65.6	59.4
		4.2	3.7	2.9	88.1	69.0
		3.9	3.6	3.0	92.3	76.9
		5.4	3.9	2.8	72.2	51.9
		3.7	3.4	2.8	91.9	75.7
		4.1	3.7	2.0	90.2	48.8
		6.4	5.2	4.2	81.3	65.6
		3.7	3.4	2.9	91.9	78.4
		3.8	3.6	3.3	94.7	86.8
		4.2	3.7	2.9	88.1	69.0
	AVG	4.6	3.9	3.0	86.3	67.2
	S.D.	1.0	0.5	0.6	9.0	11.3
6" OGDL		5.6	4.5	4.3	80.4	76.8
		4.8	4.3	3.5	89.6	72.9
		4.7	4.2	3.5	89.4	74.5
		4.7	4.4	3.7	93.6	78.7
		4.6	4.4	3.6	95.7	78.3
		5.3	4.6	4.4	86.8	83.0
		5.3	4.0	3.9	75.5	73.6
	AVG	5.0	4.3	3.8	87.3	76.8
	S.D.	0.4	0.2	0.3	6.6	3.3

TABLE 4A: 1992 FWD CORNER TEST DATA FOR THE BLOOMINGTON SECTIONS

SECTION DESCRIPTION	JOINT TYPE		D0 (mils)	D1 (mils)	D5 (mils)	JOINT LTE	SHLDR LTE
CONTROL	DOWEL		10.6	9.3	3.5	87.7	33.0
			8.8	8.0	4.8	90.9	54.5
			11.6	10.5	2.3	90.5	19.8
			10.7	9.3	2.4	86.9	22.4
			8.9	7.7	2.6	86.5	29.2
			9.9	8.0	5.1	80.8	51.5
			10.0	7.7	4.6	77.0	46.0
			8.9	7.8	3.6	87.6	40.4
			8.0	6.8	5.0	85.0	62.5
			7.3	6.3	4.6	86.3	63.0
		AVG	9.5	8.1	3.9	85.9	42.2
		S.D.	1.3	1.2	1.1	4.0	15.0
	HINGE		8.2	8.0	1.9	97.6	23.2
			5.3	5.4	3.4	101.9	64.2
			7.1	6.3	2.9	88.7	40.8
			5.9	5.6	2.0	94.9	33.9
			4.5	4.4	3.0	97.8	66.7
			5.7	5.5	2.3	96.5	40.4
			5.1	4.7	2.9	92.2	56.9
			5.6	5.4	3.5	96.4	62.5
			5.2	4.8	3.6	92.3	69.2
		AVG	5.8	5.6	2.8	95.4	50.9
		S.D.	1.1	1.0	0.6	3.6	15.6

TABLE 4B: 1992 FWD CORNER TEST DATA FOR THE BLOOMINGTON SECTIONS

SECTION DESCRIPTION	JOINT TYPE		D0 (mils)	D1 (mils)	D5 (mils)	JOINT LTE	SHLDR LTE
6" OGDL	DOWEL		5.7	4.8	3.6	84.2	63.2
			6.2	4.7	4.0	75.8	64.5
			5.8	4.5	4.5	77.6	77.6
			5.4	4.4	3.8	81.5	70.4
			5.7	4.2	4.0	73.7	70.2
			5.2	3.6	3.7	69.2	71.2
			5.4	4.2	2.8	77.8	51.9
			4.7	3.9	3.6	83.0	76.6
			5.4	4.0	3.9	74.1	72.2
			6.2	4.2	3.4	67.7	54.8
			6.3	3.6	3.7	57.1	58.7
			5.0	3.3	3.6	66.0	72.0
			6.6	5.0	4.5	75.8	68.2
			6.1	3.8	5.2	62.3	85.2
		AVG	5.7	4.2	3.9	73.3	68.3
		S.D.	0.5	0.5	0.6	7.6	8.7
	HINGE		3.7	3.5	2.6	94.6	70.3
			3.6	3.6	2.9	100.0	80.6
			4.8	4.5	3.0	93.8	62.5
			3.5	3.3	2.9	94.3	82.9
			4.0	4.0	2.9	100.0	72.5
			4.2	4.0	2.9	95.2	69.0
			3.2	3.2	2.2	100.0	68.8
			3.5	3.2	2.6	91.4	74.3
			3.8	3.3	2.6	86.8	68.4
			4.8	4.5	3.0	93.8	62.5
			5.0	3.9	2.1	78.0	42.0
			3.4	3.3	3.0	97.1	88.2
			6.6	5.2	3.8	78.8	57.6
			5.4	3.6	3.7	66.7	68.5
		AVG	4.3	3.8	2.9	90.8	69.2
		S.D.	0.9	0.6	0.5	9.5	11.0

TABLE 5: 1991 FWD EDGE TEST DATA FOR THE BLOOMINGTON SECTIONS

SECTION DESCRIPTION		DO (mils)	D1 (mils)	D2 (mils)	D3 (mils)	D5 (mils)	AREA (inches)	SHLDR LTE
CONTROL		2.5	2.6	2.4	2.0	2.7	34.80	108.0
		2.0	2.7	2.4	2.0	2.6	42.60	130.0
		3.0	2.5	2.2	1.9	2.4	28.60	80.0
		2.7	2.6	2.2	2.0	2.4	31.78	88.9
		3.4	3.0	2.7	2.5	3.2	30.53	94.1
		2.7	2.6	2.4	2.0	2.1	32.67	77.8
		3.0	2.8	2.6	2.2	1.9	32.00	63.3
		3.0	2.8	2.5	2.2	1.9	31.60	63.3
		3.2	2.8	2.6	2.2	2.7	30.38	84.4
		2.6	2.5	2.2	2.0	2.4	32.31	92.3
	AVG	2.8	2.7	2.4	2.1	2.4	32.73	88.2
	S.D.	0.4	0.2	0.2	0.2	0.4	3.63	19.0
6" OGDL		3.6	3.0	2.7	2.5	2.7	29.17	75.0
		3.7	3.3	2.9	2.6	2.8	30.32	75.7
		3.4	2.9	2.7	2.4	2.7	30.00	79.4
		3.0	2.8	2.6	2.2	2.7	32.00	90.0
		3.5	3.3	2.9	2.7	3.0	31.89	85.7
		3.3	3.2	2.8	2.6	2.9	32.55	87.9
		3.3	3.2	2.8	2.5	2.9	32.36	87.9
	AVG	3.4	3.1	2.8	2.5	2.8	31.18	83.1
	S.D.	0.2	0.2	0.1	0.2	0.1	1.23	5.8

TABLE 6: 1992 FWD EDGE TEST DATA FOR THE BLOOMINGTON SECTIONS

SECTION DESCRIPTION		D0 (mils)	D1 (mils)	D2 (mils)	D3 (mils)	D5 (mils)	AREA (inches)	SHLDR LTE
CONTROL		5.2	5.1	4.4	4.1	2.6	32.65	50.0
		4.8	4.5	3.9	3.4	2.8	31.25	58.3
		6.8	6.2	5.4	4.4	2.6	30.35	38.2
		4.5	4.2	3.8	3.3	2.7	31.73	60.0
		3.8	3.7	3.0	2.6	2.3	31.26	60.5
		3.8	3.6	3.3	3.0	2.9	32.53	76.3
		3.7	3.2	2.9	2.5	2.8	29.84	75.7
		3.9	3.8	3.4	3.0	2.2	32.77	56.4
		4.2	3.9	3.5	3.0	3.8	31.43	90.5
		3.8	3.6	3.2	2.8	3.3	31.89	86.8
	AVG	4.5	4.2	3.7	3.2	2.8	31.57	65.3
	S.D.	0.9	0.8	0.7	0.6	0.4	0.91	15.7
6" OGDL		3.5	3.2	2.9	2.6	2.1	31.37	60.0
		3.7	3.2	2.9	2.6	2.5	30.00	67.6
		4.6	4.4	4.1	3.7	2.8	33.00	60.9
		3.5	3.4	3.0	2.8	3.2	32.74	91.4
		3.6	3.5	3.2	2.8	3.3	33.00	91.7
		3.6	3.5	3.2	2.8	2.9	33.00	80.6
		2.5	3.2	2.9	2.5	2.0	41.28	80.0
		3.5	3.2	2.8	2.7	2.3	31.20	65.7
		3.4	3.0	2.8	2.5	2.7	30.88	79.4
		3.6	3.4	3.2	2.7	2.7	32.50	75.0
		3.5	3.5	3.0	2.7	3.3	32.91	94.3
		3.2	2.9	2.6	2.3	2.5	30.94	78.1
		5.5	5.1	4.5	3.8	3.7	31.09	67.3
		4.1	3.6	3.3	2.8	3.2	30.29	78.0
	AVG	3.7	3.5	3.2	2.8	2.8	32.44	76.4
	S.D.	0.7	0.6	0.5	0.4	0.5	2.66	10.7

TABLE 7: 1991 FWD CENTER PANEL TEST DATA FOR THE BLOOMINGTON SECTIONS

SECTION DESCRIPTION		D0 (mils)	D1 (mils)	D2 (mils)	D3 (mils)	AREA (inches)	ERI (KSI)
CONTROL		2.0	1.8	1.7	1.5	31.50	15.97
		1.8	1.7	1.5	1.4	32.00	16.55
		2.2	1.9	1.7	1.6	30.00	15.41
		2.0	1.8	1.6	1.5	30.90	15.97
		1.7	1.8	1.6	1.5	35.29	15.97
		1.8	1.8	1.6	1.5	33.67	15.97
		2.1	1.9	1.7	1.5	30.86	15.97
		2.0	2.0	1.8	1.6	33.60	15.41
		2.0	1.9	1.7	1.5	32.10	15.97
		2.0	1.7	1.6	1.4	30.00	16.55
	AVG	2.0	1.8	1.7	1.5	31.99	15.97
	S.D.	0.2	0.1	0.1	0.1	1.64	0.36
6" OGDL		2.2	2.2	2.1	1.9	34.64	13.78
		2.0	2.0	1.9	1.8	34.80	14.31
		2.1	1.9	1.8	1.7	32.00	14.86
		2.1	2.0	1.9	1.8	33.43	14.31
		2.1	2.0	1.8	1.7	32.57	14.86
		2.0	1.9	1.7	1.6	32.40	15.41
		2.1	2.0	1.8	1.7	32.57	14.86
	AVG	2.1	2.0	1.9	1.7	33.20	14.63
	S.D.	0.1	0.1	0.1	0.1	1.04	0.49

TABLE 8: 1992 FWD CENTER PANEL TEST DATA FOR THE BLOOMINGTON SECTIONS

SECTION DESCRIPTION		D0 (mils)	D1 (mils)	D2 (mils)	D3 (mils)	AREA (inches)	ERI (KSI)
CONTROL		1.9	1.8	1.6	1.5	32.21	15.97
		2.1	2.0	1.7	1.5	31.43	15.97
		2.0	1.8	1.6	1.5	30.90	15.97
		2.0	1.8	1.6	1.5	30.90	15.97
		2.1	2.0	1.7	1.5	31.43	15.97
		1.9	1.8	1.6	1.5	32.21	15.97
		1.8	1.7	1.5	1.4	32.00	16.55
		1.9	1.9	1.7	1.6	33.79	15.41
		1.9	1.8	1.7	1.5	32.84	15.97
		1.9	1.7	1.6	1.4	31.26	16.55
	AVG	2.0	1.8	1.6	1.5	31.90	16.03
	S.D.	0.1	0.1	0.1	0.1	0.87	0.31
6" OGDL		2.1	2.1	2.1	1.8	35.14	14.31
		2.4	2.3	2.0	1.8	32.00	14.31
		2.6	2.5	2.3	2.0	32.77	13.26
		2.4	2.4	2.1	1.9	33.25	13.78
		2.4	2.1	2.0	1.8	31.00	14.31
		2.3	1.9	1.8	1.6	29.48	15.41
		2.0	1.9	1.7	1.6	32.40	15.41
		1.9	1.8	1.6	1.3	31.58	17.13
		2.3	2.1	1.8	1.7	30.78	14.86
		2.5	2.3	2.0	1.8	30.96	14.31
		2.6	2.4	2.1	1.8	30.92	14.31
		2.7	2.5	2.3	1.9	31.56	13.78
		2.8	2.6	2.4	2.0	31.71	13.26
		2.4	2.3	2.0	1.8	32.00	14.31
	AVG	2.4	2.2	2.0	1.8	31.83	14.48
	S.D.	0.2	0.2	0.2	0.2	1.29	0.96

TABLE 9: 1991 FWD EDGE TEST DATA FOR THE LASALLE/PERU CONTROL AND ASPHALT CEMENT TREATED OGDL TEST SECTIONS

SECTION	# OF TESTS	D0 (mils) AVG.	D0 (mils) S.D.	D0 (mils) CV(%)	D1 (mils) AVG.	D1 (mils) S.D.	D1 (mils) CV(%)	D2 (mils) AVG.	D2 (mils) S.D.	D2 (mils) CV(%)
CONTROL	14	2.47	0.16	6.48	2.34	0.19	8.12	2.08	0.19	9.13
4" OGDL	16	2.95	0.27	9.49	2.79	0.27	10.04	2.42	0.23	9.92
5" OGDL	14	3.11	0.34	11.25	2.97	0.37	12.79	2.60	0.27	10.77
4" OGDL ON FILTER LAYER	17	3.09	0.26	8.74	2.87	0.23	8.36	2.53	0.20	7.91

SECTION	# OF TESTS	D3 (mils) AVG.	D3 (mils) S.D.	D3 (mils) CV(%)	CRACK LTE AVG.	CRACK LTE S.D.	CRACK LTE CV(%)
CONTROL	14	1.83	0.16	8.74	95.00	3.32	3.62
4" OGDL	16	2.05	0.21	10.73	94.64	2.43	2.65
5" OGDL	14	2.21	0.25	11.76	95.38	2.65	2.87
4" OGDL ON FILTER LAYER	17	2.17	0.17	8.29	92.82	1.89	2.10

TABLE 10: 1991 FWD EDGE TEST DATA FOR THE LASALLE/PERU PORTLAND CEMENT TREATED OGDL TEST SECTIONS

SECTION	# OF TESTS	DO (mils) AVG.	DO (mils) S.D.	DO (mils) CV(%)	D1 (mils) AVG.	D1 (mils) S.D.	D1 (mils) CV(%)	D2 (mils) AVG.	D2 (mils) S.D.	D2 (mils) CV(%)
4" OGDL	14	2.39	0.21	9.21	2.21	0.21	9.95	1.96	0.17	9.18
5" OGDL	17	2.40	0.25	10.83	2.23	0.23	10.31	1.99	0.20	10.05
4" OGDL ON FILTER LAYER	17	2.84	0.82	29.58	2.62	0.80	31.68	2.31	0.75	33.33

SECTION	# OF TESTS	D3 (mils) AVG.	D3 (mils) S.D.	D3 (mils) CV(%)	CRACK LTE AVG.	CRACK LTE S.D.	CRACK LTE CV(%)
4" OGDL	14	1.70	0.14	8.24	92.56	3.21	3.60
5" OGDL	17	1.70	0.14	8.82	92.93	3.66	4.06
4" OGDL ON FILTER LAYER	17	1.98	0.64	33.33	91.98	2.26	2.73

TABLE 11: 1992 FWD EDGE TEST DATA FOR THE LASALLE/PERU CONTROL AND ASPHALT CEMENT TREATED OGDL TEST SECTIONS

SECTION	# OF TESTS	D0 (mils) AVG.	D0 (mils) S.D.	D0 (mils) CV(%)	D1 (mils) AVG.	D1 (mils) S.D.	D1 (mils) CV(%)	D2 (mils) AVG.	D2 (mils) S.D.	D2 (mils) CV(%)	D3 (mils) AVG.	D3 (mils) S.D.	D3 (mils) CV(%)
CONTROL	12	3.27	0.44	14.07	2.98	0.34	12.08	2.60	0.23	9.23	2.22	0.17	8.11
4" OGDL	15	3.44	0.58	17.44	3.12	0.50	16.67	2.70	0.36	13.70	2.25	0.26	12.00
5" OGDL	16	3.57	0.41	12.04	3.30	0.37	11.82	2.89	0.28	10.03	2.47	0.24	10.12
4" OGDL ON FILTER LAYER	16	3.61	0.37	10.53	3.46	0.38	11.27	3.00	0.27	9.33	2.54	0.23	9.45

SECTION	# OF TESTS	D5 (mils) AVG.	D5 (mils) S.D.	D5 (mils) CV(%)	CRACK LTE AVG.	CRACK LTE S.D.	CRACK LTE CV(%)	SHOULDER LTE AVG.	SHOULDER LTE S.D.	SHOULDER LTE CV(%)
CONTROL	12	3.21	0.42	13.40	91.44	3.98	4.55	97.78	1.97	2.11
4" OGDL	15	3.24	0.52	16.67	90.84	5.07	5.77	94.21	2.37	2.61
5" OGDL	16	3.30	0.39	12.12	92.51	3.78	4.22	92.34	1.75	1.96
4" OGDL ON FILTER LAYER	16	3.42	0.37	11.11	95.42	2.87	3.10	94.59	2.67	2.91

TABLE 12: 1992 FWD EDGE TEST DATA FOR THE LASALLE/PERU PORTLAND CEMENT TREATED OGDL TEST SECTIONS

SECTION	# OF TESTS	D0 (mils) AVG.	D0 (mils) S.D.	D0 (mils) CV(%)	D1 (mils) AVG.	D1 (mils) S.D.	D1 (mils) CV(%)	D2 (mils) AVG.	D2 (mils) S.D.	D2 (mils) CV(%)	D3 (mils) AVG.	D3 (mils) S.D.	D3 (mils) CV(%)
4" OGDL	9	3.01	0.31	10.88	2.85	0.30	11.23	2.56	0.25	10.16	2.19	0.23	10.96
5" OGDL	17	2.85	0.25	9.12	2.68	0.23	8.96	2.35	0.20	8.94	2.00	0.18	9.50
4" OGDL ON FILTER LAYER	16	3.54	0.84	24.29	3.31	0.71	22.05	2.92	0.61	19.03	2.48	0.53	0.22

SECTION	# OF TESTS	D5 (mils) AVG.	D5 (mils) S.D.	D5 (mils) CV(%)	CRACK LTE AVG.	CRACK LTE S.D.	CRACK LTE CV(%)	SHLDR LTE AVG.	SHLDR LTE S.D.	SHLDR LTE CV(%)
4" OGDL	9	2.75	0.28	10.91	94.84	2.35	2.63	91.36	2.04	2.36
5" OGDL	17	2.68	0.23	8.58	94.22	3.29	3.60	94.29	2.54	2.75
4" OGDL ON FILTER LAYER	16	3.28	0.71	22.26	93.53	3.73	3.99	92.99	4.99	5.55

TABLE 13 1991 FWD CENTER PANEL TEST DATA FOR LASALLE/PERU PORTLAND CEMENT TREATED OGDL TEST SECTIONS

SECTION DESCRIPTION	DO (mils)	D1 (mils)	D2 (mils)	D3 (mils)	AREA (inches)	ERI (KSI)
4" OGDL	2.42	2.20	1.98	1.68	30.89	14.95
	2.15	2.05	1.85	1.59	32.20	15.47
	2.33	2.14	1.90	1.67	31.11	15.02
	2.55	2.33	2.08	1.83	31.06	14.15
5" OGDL	1.86	1.79	1.57	1.39	32.16	16.63
	1.87	1.84	1.61	1.38	32.57	16.66
	2.76	2.36	2.09	1.77	29.20	14.47
4" OGDL ON FILTER LAYER	2.33	2.10	1.79	1.55	30.03	15.67
	2.33	2.15	1.82	1.53	30.39	15.79

TABLE 14: 1991 FWD CENTER PANEL TEST DATA FOR LASALLE/PERU CONTROL AND ASPHALT CEMENT TREATED OGDL TEST SECTIONS

SECTION DESCRIPTION	DO (mils)	D1 (mils)	D2 (mils)	D3 (mils)	AREA (inches)	ERI (KSI)
CONTROL	2.27	2.00	1.81	1.65	30.50	15.12
	2.90	2.63	2.32	1.93	30.48	13.60
	2.01	1.76	1.58	1.40	30.12	16.54
4" OGDL	2.54	2.30	1.99	1.71	30.30	14.81
	3.05	2.81	2.49	2.04	30.87	13.03
	2.69	2.57	2.21	1.93	31.63	13.64
5" OGDL	2.61	2.36	2.12	1.84	30.83	14.08
	3.32	3.00	2.60	2.28	30.36	11.85
	3.35	3.20	2.74	2.32	31.43	11.65
	3.59	3.31	2.91	2.51	31.00	10.76
	2.95	2.68	2.37	2.03	30.67	13.10
	3.04	2.79	2.35	1.98	30.20	13.37
4" OGDL ON FILTER LAYER	3.27	2.99	2.70	2.26	31.03	11.95
	3.23	3.42	2.62	2.24	32.60	12.05

TABLE 15: 1992 FWD CENTER PANEL TEST DATA FOR LASALLE/PERU PORTLAND CEMENT TREATED OGDL TEST SECTIONS

SECTION DESCRIPTION	DO (mils)	D1 (mils)	D2 (mils)	D3 (mils)	AREA (inches)	ERI (KSI)
4" OGDL	2.94	2.82	2.62	2.23	32.76	12.10
	2.73	2.54	2.31	1.96	31.63	13.47
5" OGDL	3.13	2.90	2.51	2.21	30.98	12.20
	3.38	2.92	2.49	2.06	28.86	12.95
	2.31	2.20	1.90	1.61	31.48	15.35
4" OGDL ON FILTER LAYER	3.58	3.27	2.72	2.24	29.83	12.05
	4.54	4.54	4.01	3.32	32.99	7.37

TABLE 16: 1992 FWD CENTER PANEL TEST DATA FOR LASALLE/PERU CONTROL AND ASPHALT CEMENT TREATED OGDL TEST SECTIONS

SECTION DESCRIPTION	DO (mils)	D1 (mils)	D2 (mils)	D3 (mils)	AREA (inches)	ERI (KSI)
CONTROL	2.74	2.47	2.20	1.89	30.59	13.82
	2.38	2.15	1.84	1.61	30.19	15.35
	2.43	2.36	2.12	1.89	32.79	13.82
4" OGDL	2.87	2.72	2.30	1.91	30.98	13.70
	3.27	3.04	2.58	2.16	30.59	12.47
	3.04	2.77	2.42	2.03	30.49	13.13
	2.67	2.48	2.25	1.90	31.53	13.79
5" OGDL	3.43	3.31	2.84	2.38	31.68	11.39
	3.39	3.08	2.73	2.38	30.78	11.39
	3.66	3.35	2.92	2.57	30.77	10.48
4" OGDL ON FILTER LAYER	3.26	2.98	2.75	2.39	31.49	11.31
	3.72	3.76	3.13	2.62	32.45	10.25

TABLE 17: TOTAL OUTFLOW DATA FOR THE BLOOMINGTON SECTIONS

RAIN (in)	CONTROL (gal)	6" OGDL (gal)
0.24	88.0	18.2
0.31	49.4	5.1
0.46	174.9	69.3
0.49	508.6	305.2
1.27	676.5	806.0
1.43	702.0	536.2
1.46	315.2	178.9
	R^2=0.53	R^2=0.48

TABLE 18: OUTFLOW VERSUS RAINFALL COMPARISON FOR THE BLOOMINGTON SECTIONS FOR A 12' LANE WIDTH (EXCLUDES THE 10' SHOULDER)

RAIN (in)	CONTROL (%)	6" OGDL (%)
0.24	9.8	2.0
0.31	4.3	0.4
0.46	10.2	4.0
0.49	27.8	16.7
1.27	14.2	17.0
1.43	13.1	10.0
1.46	5.8	3.3
AVG	12.2	7.6
S.D.	7.2	6.5

TABLE 19: TOTAL DRAIN TIME DATA FOR THE BLOOMINGTON SECTIONS

RAIN (in)	CONTROL (hr)	6" OGDL (hr)
0.24	4.50	2.33
0.31	3.33	1.00
0.46	5.83	4.83
0.49	12.33	18.33
1.27	20.00	29.00
1.43	12.33	19.17
1.46	7.50	11.50
	AVG. 9.40	AVG. 12.31
	S.D. 5.87	S.D. 10.40

TABLE 20: PEAK OUTFLOW DATA FOR THE BLOOMINGTON SECTIONS

CONTROL		6" OGDL	
RAIN (in)	OUTFLOW (gal)	RAIN (in)	OUTFLOW (gal)
1.27	125.5	1.27	123.8
0.31	5.1	0.31	—
0.46	13.6	0.46	5.1
0.24	8.0	0.24	2.3
1.42	23.9	1.42	11.4
0.48	29.0	0.49	9.7
AVG. RAIN=0.70		AVG. RAIN=0.78	
AVG. PEAK OUTFLOW=34.2		AVG. PEAK OUTFLOW=30.5	
R^2=0.40		R^2=0.32	

TABLE 21: TOTAL OUTFLOW DATA FOR THE LASALLE/PERU CONTROL AND PORTLAND CEMENT TREATED OGDL TEST SECTIONS

RAIN (in)	CONTROL (gal)	4" OGDL ON FILTER LAYER (gal)	5" OGDL (gal)	4" OGDL (gal)
0.11	----	223.2	340.3	322.6
0.12	----	430.5	493.9	274.4
0.21	----	665.4	674.0	244.9
0.22	66.6	1124.5	1020.3	487.0
0.23	335.2	771.2	747.5	380.7
0.37	168.7	1896.7	1921.7	1193.2
0.57	247.9	----	1868.4	1061.1
0.62	78.6	1674.9	2172.3	873.3
0.82	----	1804.0	2092.3	1375.3
1.29	443.4	4040.9	3323.5	1289.7
1.66	364.2	6674.9	8000.6	4058.6
	R^2=0.42	R^2=0.92	R^2=0.86	R^2=0.78

TABLE 22: TOTAL OUTFLOW DATA FOR THE LASALLE/PERU CONTROL AND ASPHALT CEMENT TREATED OGDL TEST SECTIONS

RAIN (in)	CONTROL (gal)	4" OGDL ON FILTER LAYER (gal)	5" OGDL (gal)	4" OGDL (gal)
0.11	---	341.0	177.2	298.4
0.12	---	460.1	----	246.2
0.21	---	581.7	149.4	492.6
0.22	66.6	1090.4	202.6	606.2
0.23	335.2	1049.6	351.4	671.9
0.37	168.7	3292.8	1293.9	1502.4
0.57	247.9	----	349.6	734.8
0.62	78.6	3065.1	761.5	1818.9
0.82	----	2143.4	----	2232.7
1.29	443.4	----	2343.0	2861.5
1.66	364.2	9775.7	3701.6	3755.1
	R^2=0.42	R^2=0.89	R^2=0.89	R^2=0.87

TABLE 23: OUTFLOW VERSUS RAINFALL COMPARISON FOR THE CONTROL AND PORTLAND CEMENT TREATED OGDL TEST SECTIONS FOR A 12' LANE WIDTH (EXCLUDES THE 10' SHOULDER)

RAIN (in)	CONTROL (%)	4" OGDL ON FILTER LAYER (%)	5" OGDL (%)	4" OGDL (%)
0.11	---	54.3	82.8	78.5
0.12	---	95.9	110.0	61.1
0.21	---	84.8	85.9	31.2
0.22	8.1	136.6	124.0	59.2
0.23	39.0	89.7	86.9	44.3
0.37	12.2	137.0	138.8	86.2
0.57	11.6	---	87.6	49.8
0.62	3.4	72.2	93.7	37.7
0.82	---	58.8	68.2	44.8
1.29	9.2	83.8	68.9	26.7
1.66	5.9	107.5	128.9	65.4
AVG.	8.1	92.1	97.8	53.2
S.D.	10.8	36.9	23.0	18.0

TABLE 24: OUTFLOW VERSUS RAINFALL COMPARISON FOR THE CONTROL AND ASPHALT CEMENT TREATED OGDL TEST SECTIONS FOR A 12' LANE WIDTH (EXCLUDES THE 10' SHOULDER)

RAIN (in)	CONTROL (%)	4" OGDL ON FILTER LAYER (%)	5" OGDL (%)	4" OGDL (%)
0.11	---	83.0	43.1	72.6
0.12	---	102.5	---	54.8
0.21	---	74.1	19.0	62.8
0.22	8.1	132.5	24.6	73.7
0.23	39.0	122.0	40.9	78.1
0.37	12.2	237.9	93.5	108.6
0.57	11.6	---	16.4	34.5
0.62	3.4	132.2	32.8	78.4
0.82	---	69.9	---	72.8
1.29	9.2	---	48.6	59.2
1.66	5.9	157.5	59.6	60.5
AVG.	8.1	123.5	42.1	68.7
S.D.	10.8	49.2	22.6	17.5

TABLE 25: OUTFLOW VERSUS RAINFALL COMPARISON FOR THE CONTROL AND PORTLAND CEMENT TREATED OGDL TEST SECTIONS FOR A 22' LANE WIDTH (INCLUDES THE 10' SHOULDER)

RAIN (in)	CONTROL (%)	4" OGDL ON FILTER LAYER (%)	5" OGDL (%)	4" OGDL (%)
0.11	---	29.6	45.1	42.8
0.12	---	52.3	60.0	33.3
0.21	---	46.2	46.8	17.0
0.22	4.4	74.6	67.7	32.3
0.23	21.2	48.9	47.4	24.1
0.37	6.6	74.8	75.7	47.0
0.57	6.3	---	47.8	27.2
0.62	1.8	39.4	51.1	20.5
0.82	---	32.1	37.2	24.5
1.29	5.0	45.6	37.6	14.6
1.66	3.2	58.6	70.3	35.7
AVG.	6.9	50.2	53.3	29.0
S.D.	6.0	14.8	12.5	9.8

TABLE 26: OUTFLOW VERSUS RAINFALL COMPARISON FOR THE CONTROL AND ASPHALT CEMENT TREATED OGDL TEST SECTIONS FOR A 22' LANE WIDTH (INCLUDES THE 10' SHOULDER)

RAIN (in)	CONTROL (%)	4" OGDL ON FILTER LAYER (%)	5" OGDL (%)	4" OGDL (%)
0.11	---	45.2	23.5	39.6
0.12	---	55.9	---	29.9
0.21	---	40.3	10.4	34.2
0.22	4.4	72.3	13.4	40.2
0.23	21.2	66.6	22.2	42.6
0.37	6.6	129.8	51.0	59.2
0.57	6.3	---	8.9	18.8
0.62	1.8	72.1	17.9	42.8
0.82	---	38.1	---	39.7
1.29	5.0	---	26.5	32.3
1.66	3.2	85.9	32.5	33.0
AVG.	6.9	67.4	22.9	37.5
S.D.	6.0	33.4	12.3	9.6

TABLE 27: TOTAL DRAIN TIME DATA FOR THE LASALLE/PERU CONTROL AND PORTLAND CEMENT TREATED OGDL TEST SECTIONS

RAIN (in)	CONTROL (hr)	4" OGDL ON FILTER LAYER (hr)	5" OGDL (hr)	4" OGDL (hr)
0.11	---	21.33	19.17	16.17
0.12	---	30.67	30.17	17.33
0.21	---	24.83	20.83	14.83
0.22	---	48.50	32.67	22.83
0.23	13.00	24.50	18.83	14.67
0.37	12.50	28.67	29.17	22.67
0.57	17.17	---	35.50	24.17
0.62	18.67	37.00	45.83	21.50
0.82	14.33	25.83	27.33	22.83
1.29	10.17	72.17	40.83	24.17
1.66	37.67	---	63.50	---
AVG.	17.64	34.83	33.08	21.12
S.D.	9.28	16.24	13.26	3.90

TABLE 28: TOTAL DRAIN TIME DATA FOR THE LASALLE/PERU CONTROL AND ASPHALT CEMENT TREATED OGDL TEST SECTIONS

RAIN (in)	CONTROL (hr)	4" OGDL ON FILTER LAYER (hr)	5" OGDL (hr)	4" OGDL (hr)
0.11	----	11.30	3.50	15.50
0.12	----	14.50	----	15.30
0.21	----	14.17	2.83	13.00
0.22	----	48.83	5.83	20.67
0.23	13.00	17.50	5.67	16.17
0.37	12.50	37.83	9.50	22.50
0.57	17.17	----	11.83	19.83
0.62	18.67	52.50	6.83	28.50
0.82	14.33	34.00	----	23.30
1.29	10.17	----	8.67	18.67
1.66	37.67	64.83	13.30	33.17
	AVG. 17.64	AVG. 32.83	AVG. 7.55	AVG. 20.60
	S.D. 9.28	S.D. 19.61	S.D. 3.57	S.D. 6.06

TABLE 29: PEAK OUTFLOW DATA FOR THE LASALLE/PERU CONTROL AND PORTLAND CEMENT TREATED OGDL TEST SECTIONS

CONTROL		4" OGDL ON FILTER LAYER		5" OGDL		4" OGDL	
RAIN (in)	OUTFLOW (gal)	RAIN (in)	OUTFLOW (gal)	RAIN (in)	OUTFLOW (gal)	RAIN (in)	OUTFLOW (gal)
1.23	42.1	1.22	205.6	1.16	170.4	1.24	51.1
0.23	27.9	0.23	41.5	0.23	40.3	0.23	17.6
0.55	4.6	----	----	0.52	42.0	0.52	21.6
0.32	3.7	0.34	160.2	0.37	134.6	0.37	69.9
----	---	0.21	39.8	0.21	31.8	0.21	8.5
1.66	5.5	0.53	126.7	0.58	105.6	1.66	106.2
0.16	2.1	0.22	51.7	0.22	38.1	0.22	14.8
----	---	0.61	86.9	0.60	70.4	0.62	26.7
----	---	0.11	8.5	0.11	12.5	0.11	12.5
----	---	0.82	150.5	0.82	118.7	0.82	53.4
----	---	0.12	11.4	0.12	11.9	0.12	8.5
AVG. RAIN=0.69		AVG. RAIN=0.44		AVG. RAIN=0.45		AVG. RAIN=0.45	
AVG. PEAK OUTFLOW=14.3		AVG. PEAK OUTFLOW=88.3		AVG. PEAK OUTFLOW=70.6		AVG. PEAK OUTFLOW=28.5	
R^2=0.05		R^2=0.74		R^2=0.72		R^2=0.41	

TABLE 30: PEAK OUTFLOW DATA FOR THE LASALLE/PERU CONTROL AND ASPHALT CEMENT TREATED OGDL TEST SECTIONS

CONTROL		4" OGDL ON FILTER LAYER		5" OGDL		4" OGDL	
RAIN (in)	OUTFLOW (gal)	RAIN (in)	OUTFLOW (gal)	RAIN (in)	OUTFLOW (gal)	RAIN (in)	OUTFLOW (gal)
1.23	42.1	---	---	1.16	222.1	1.16	110.8
0.23	27.9	0.19	95.4	0.23	33.5	0.23	30.1
0.55	4.6	---	---	0.52	11.9	0.51	17.6
0.32	3.7	0.32	239.4	0.37	108.5	0.37	47.7
----	---	0.19	102.2	0.21	27.8	0.21	56.8
1.66	5.5	0.44	208.5	0.48	72.7	0.51	63.6
0.16	2.1	0.20	119.8	0.22	17.0	0.22	40.3
----	---	0.37	167.6	0.60	56.8	0.61	56.8
----	---	0.10	51.1	0.10	32.9	0.11	25.0
----	---	0.82	284.6	---	----	0.82	124.4
----	---	0.11	64.2	---	----	0.11	13.1
AVG. RAIN=0.69		AVG. RAIN=0.30		AVG. RAIN=0.43		AVG. RAIN=0.44	
AVG. PEAK OUTFLOW=14.3		AVG. PEAK OUTFLOW=148.1		AVG. PEAK OUTFLOW=64.8		AVG. PEAK OUTFLOW=53.3	
R^2=0.05		R^2=0.80		R^2=0.69		R^2=0.68	

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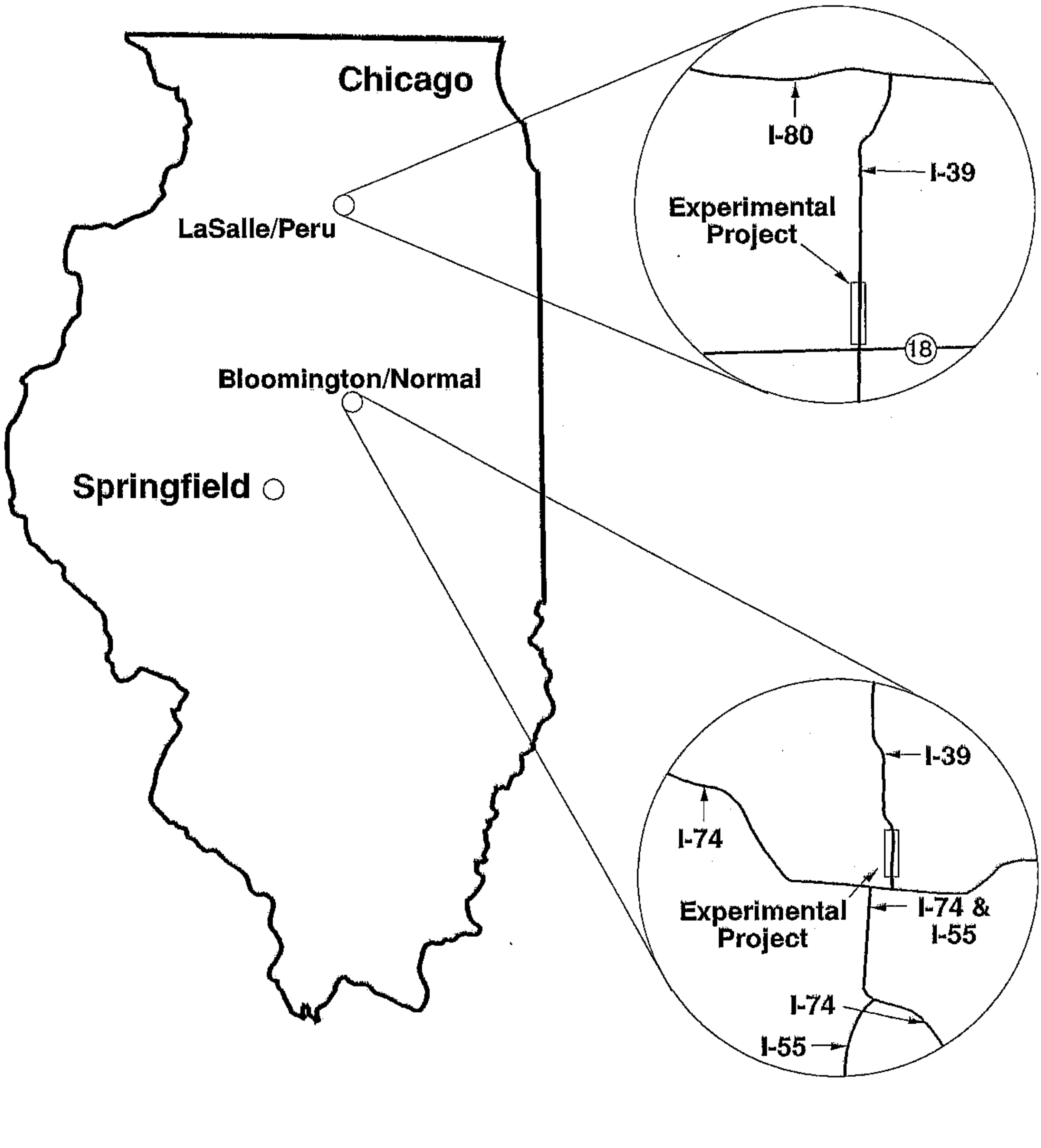


Figure 1. Experimental Project Locations

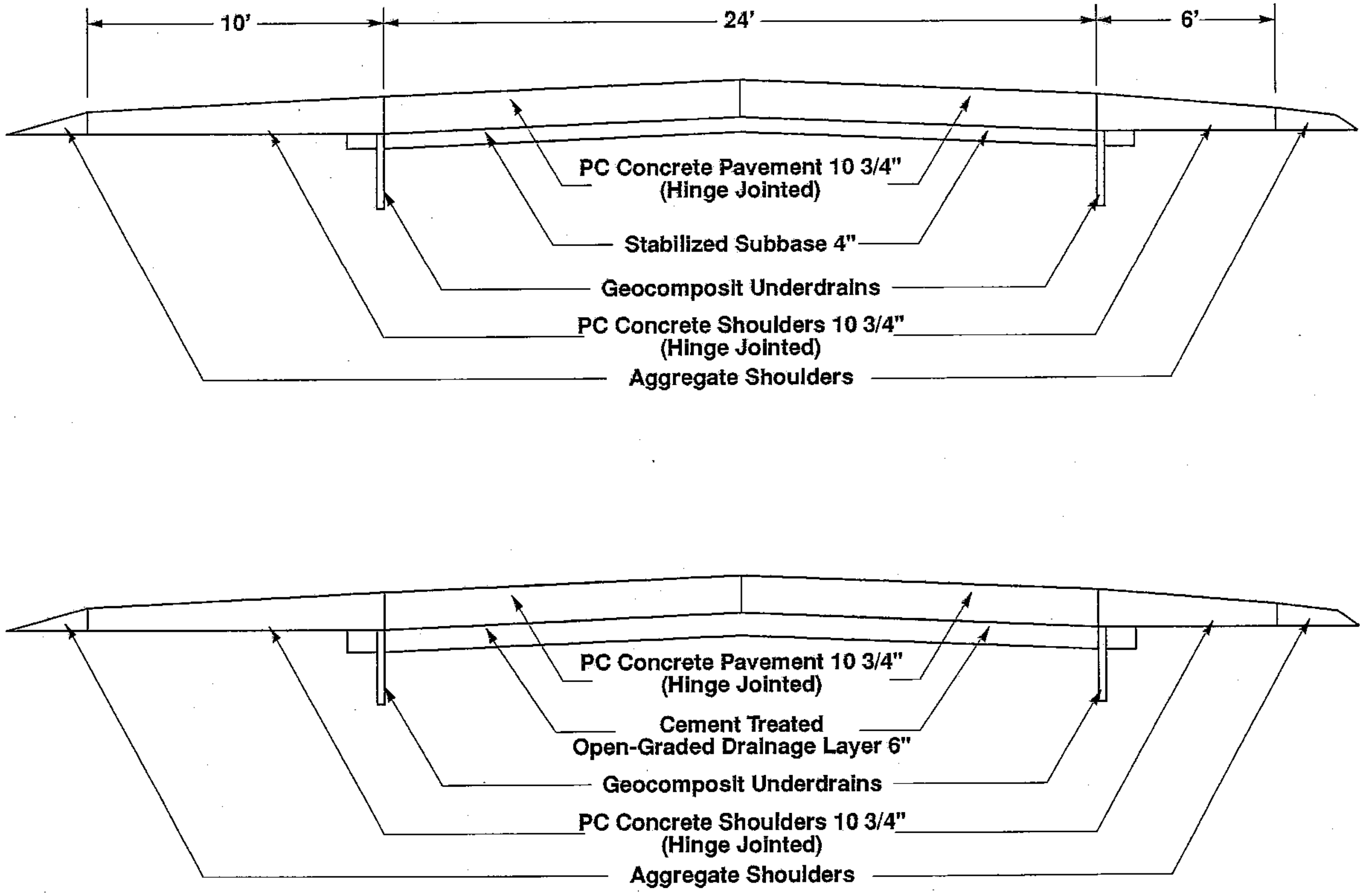


Figure 2. Bloomington Experimental Project Cross-Sections

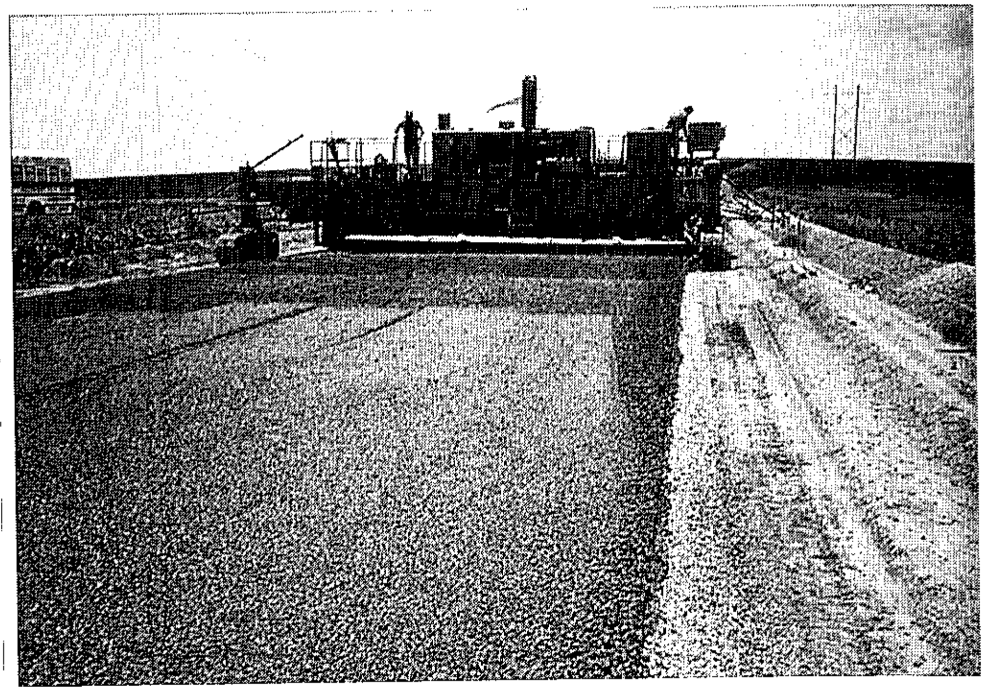


Figure 3. Rex Town and county paver used to construct the Bloomington test section.

Figure 4. Bloomington drainage layer mix after a 75 second mix time.

Figure 5. Roller consolidating the Bloomington test section.

Figure 6. Edge slump of drainage layer.

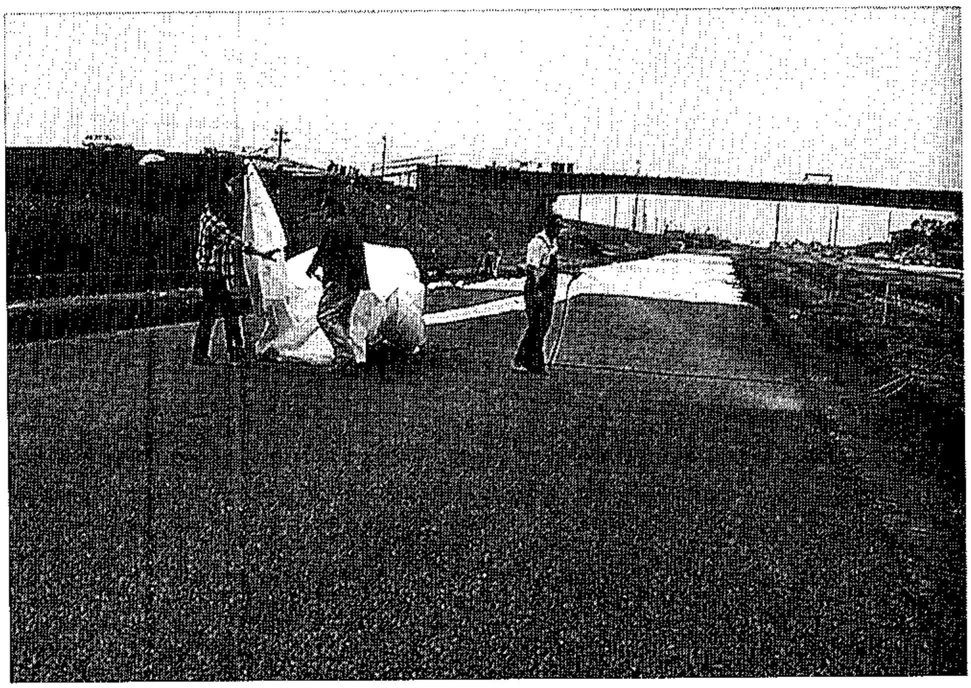


Figure 7. Curing process for the Bloomington test section.

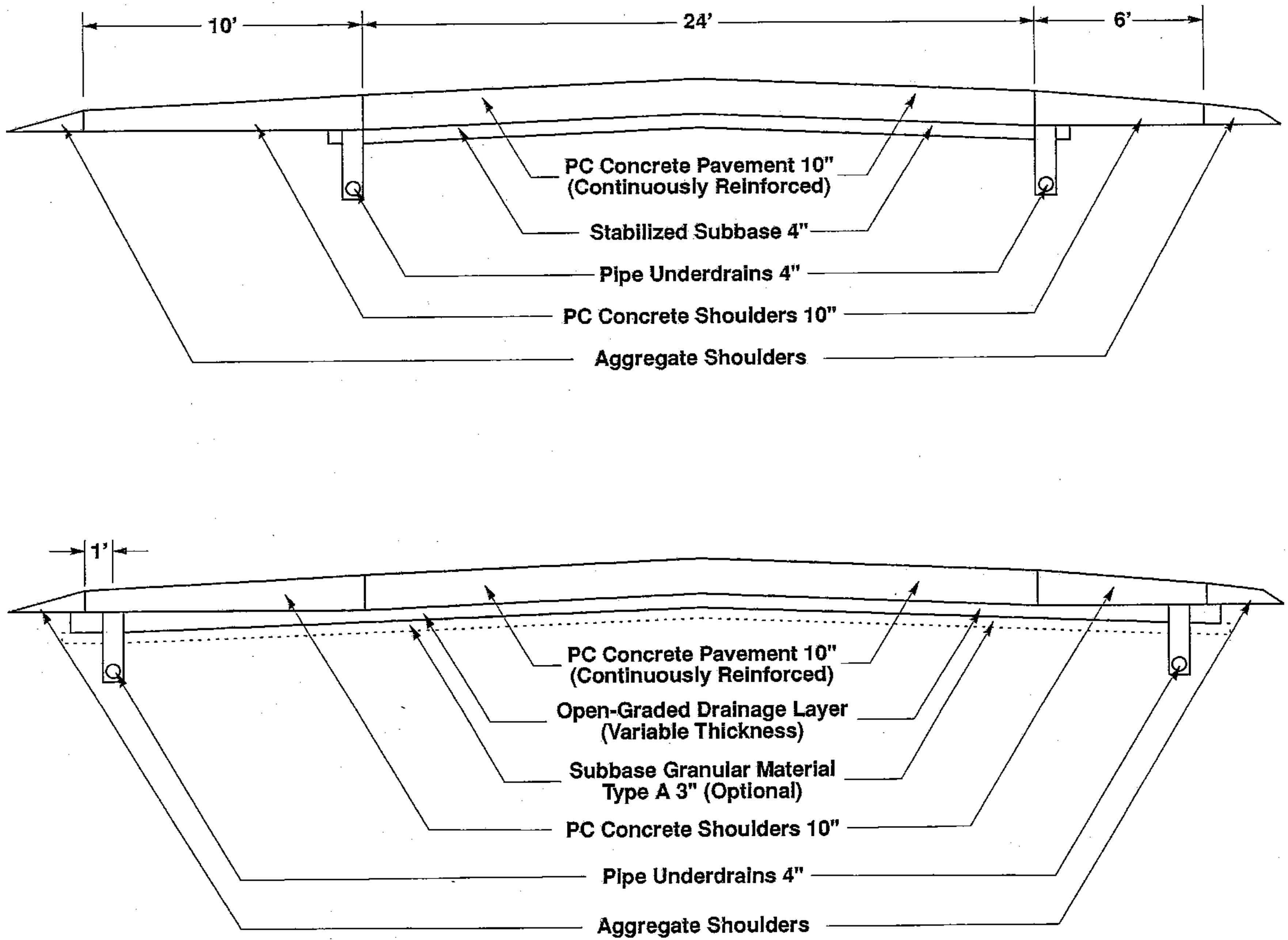


Figure 8. LaSalle/Peru Experimental Project Cross-Sections

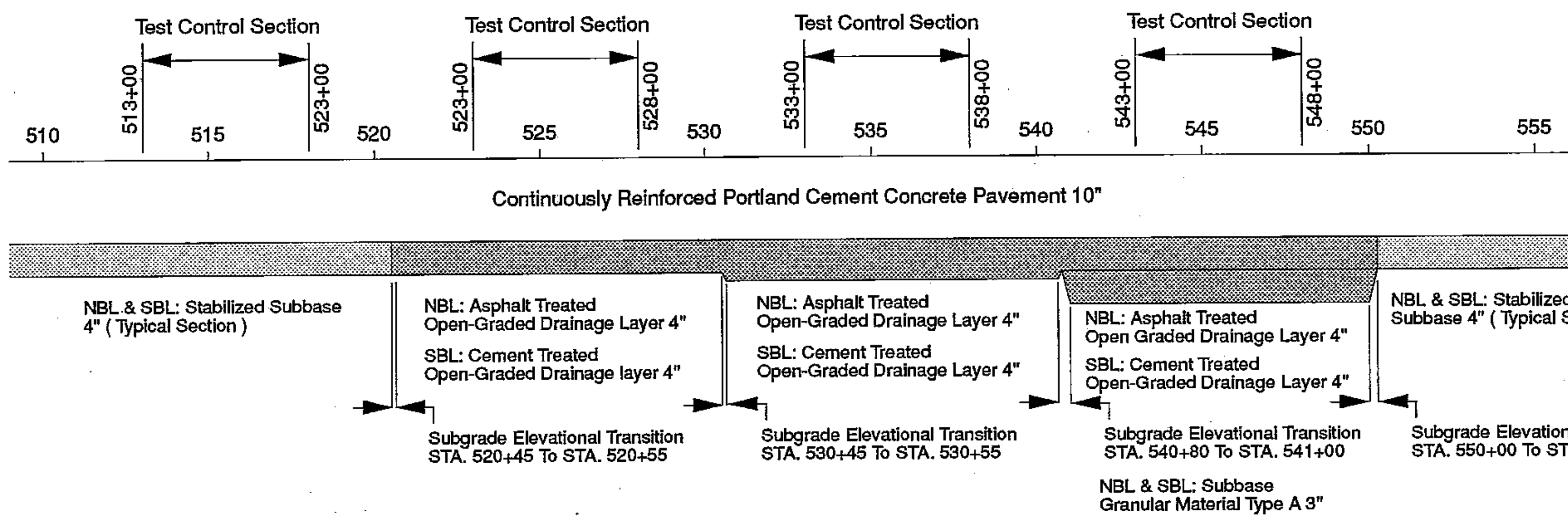


Figure 9. LaSalle/Peru Test Section Layout

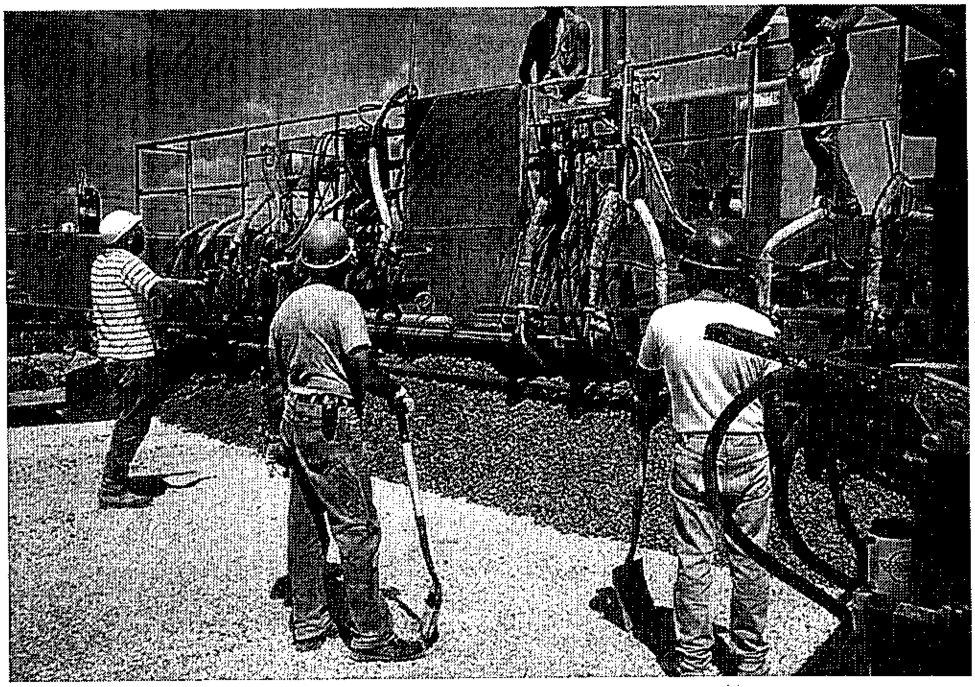


Figure 10. CMI concrete paver used on the LaSalle/Peru test sections.

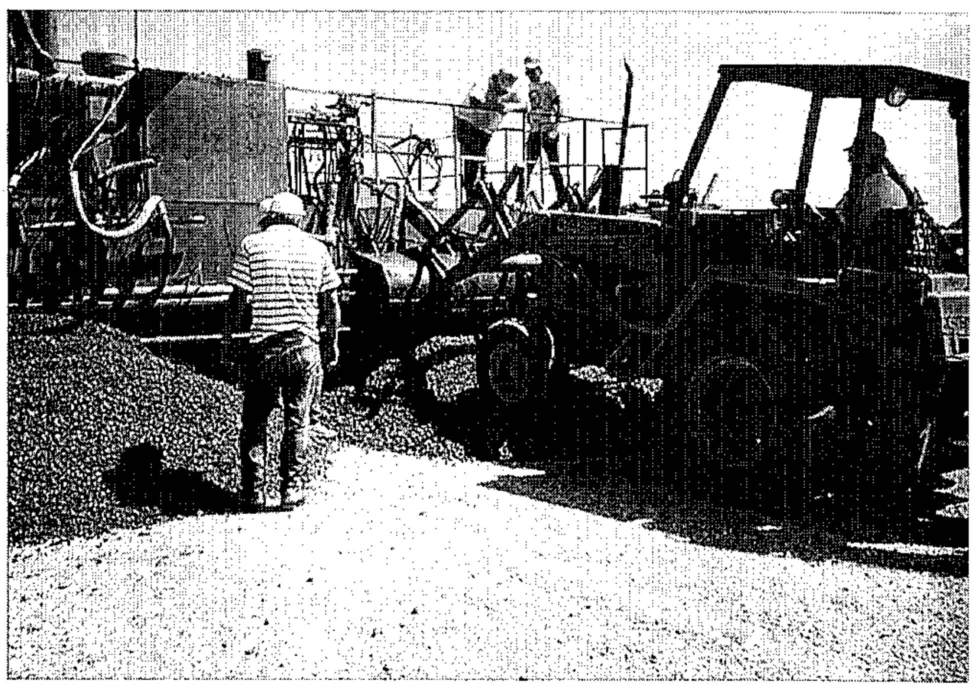


Figure 11. Front end loader spreading out the drainage layer mix.

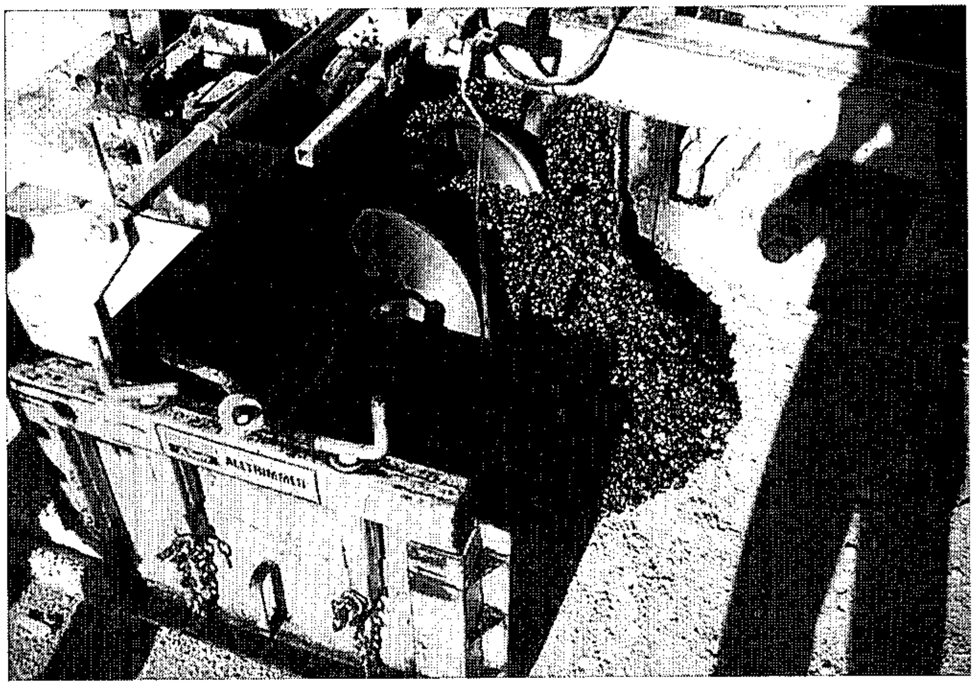


Figure 12. Asphalt paver used to place most of the drainage layers in the LaSalle/Peru test sections.

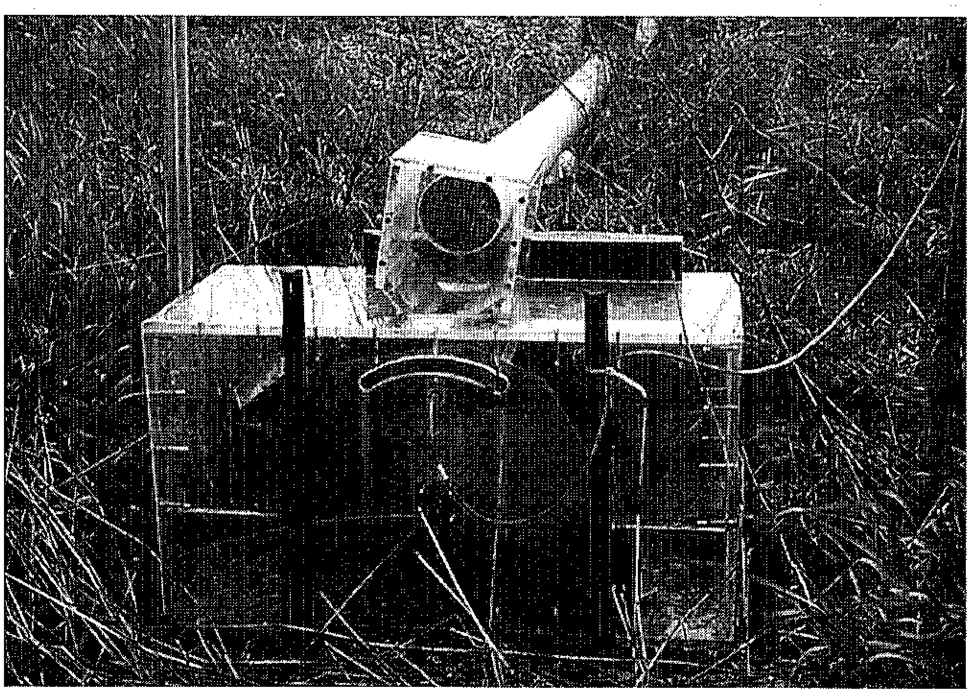


Figure 13. IDOT standard tipping bucket.

Pressure Transducer Installation Diagram

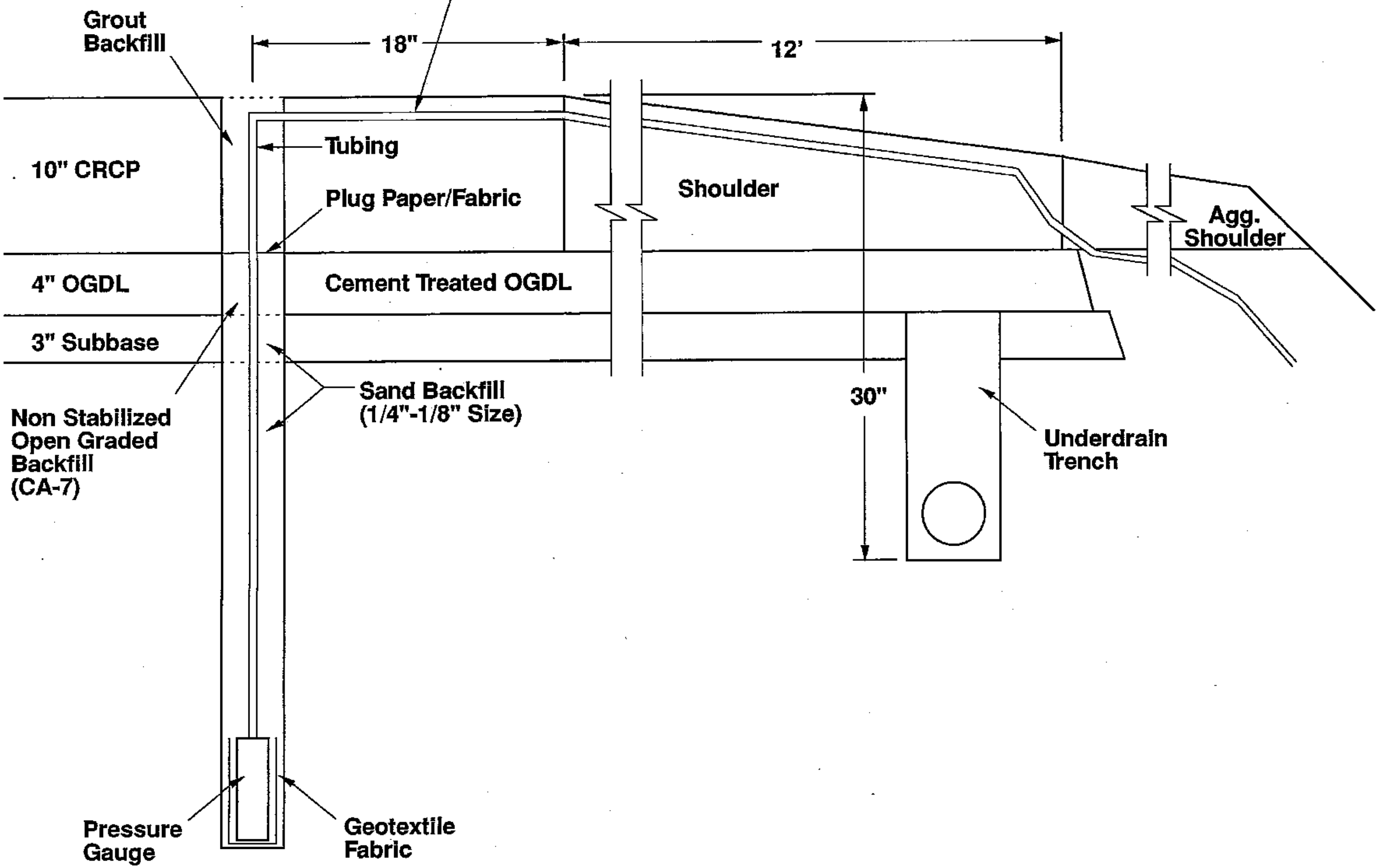


Figure 14. Pressure Transducer Installation Diagram

Testing Sequence For Hinge-Jointed Pavement

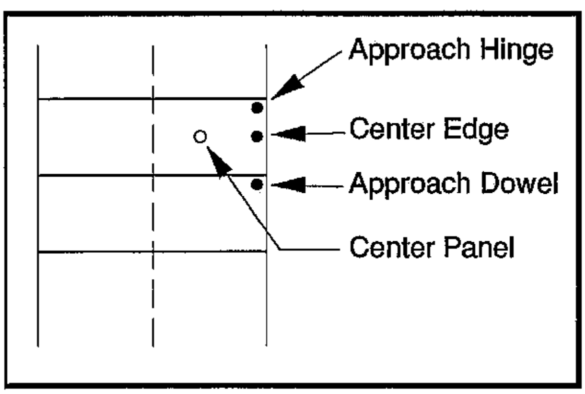
5 Locations Per Mile Post

4 Drops Per Location

- • 3 Edge of Pavement Drops With Shoulder Load Transfer Tested (5th Sensor Extended To The Right)
- ○ 1 Center Panel Test (3 Drops For Ease of Analysis)

4, 8, & 12 Kip Drops

2 or 3 Temperatures @ 4 ~5 Inches



Detail

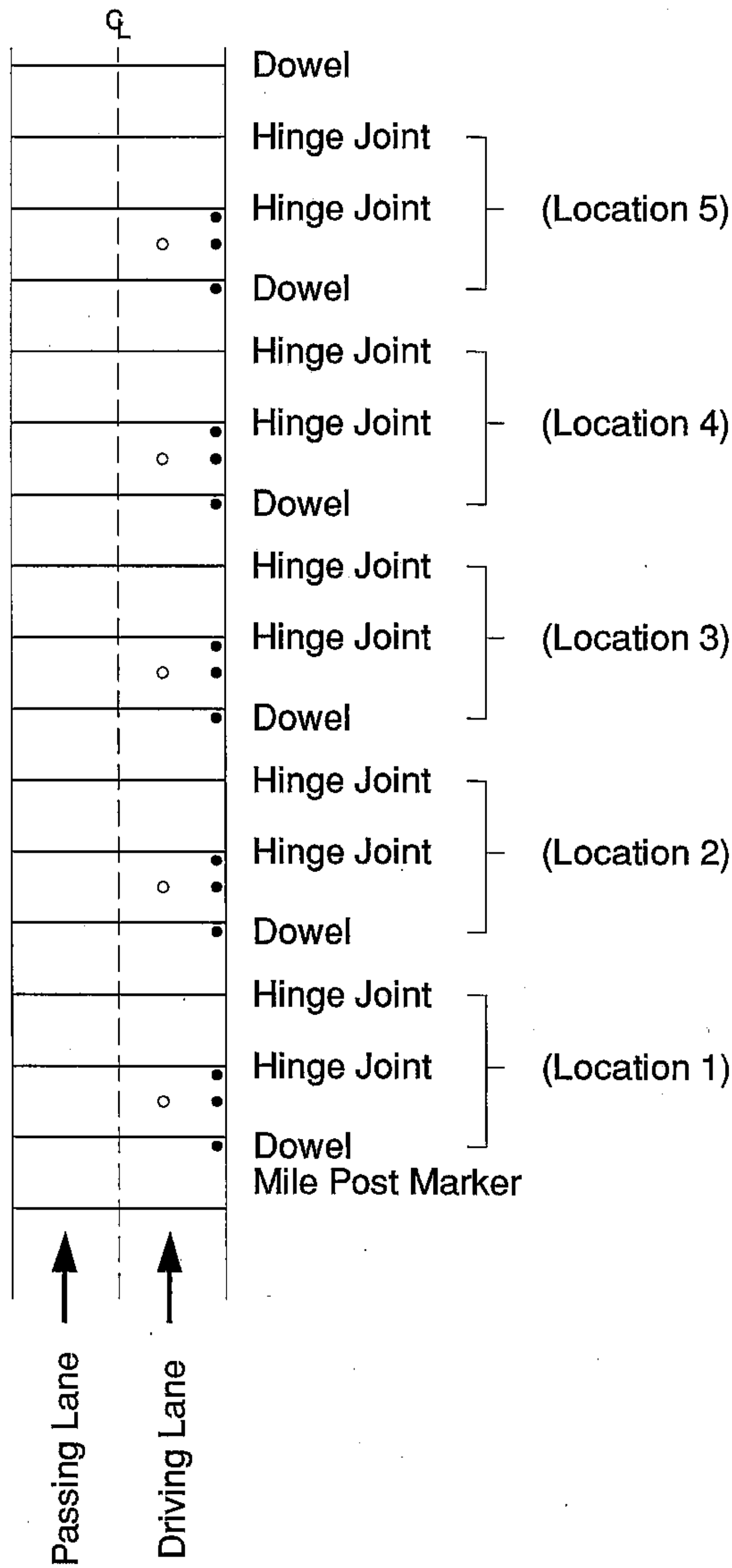
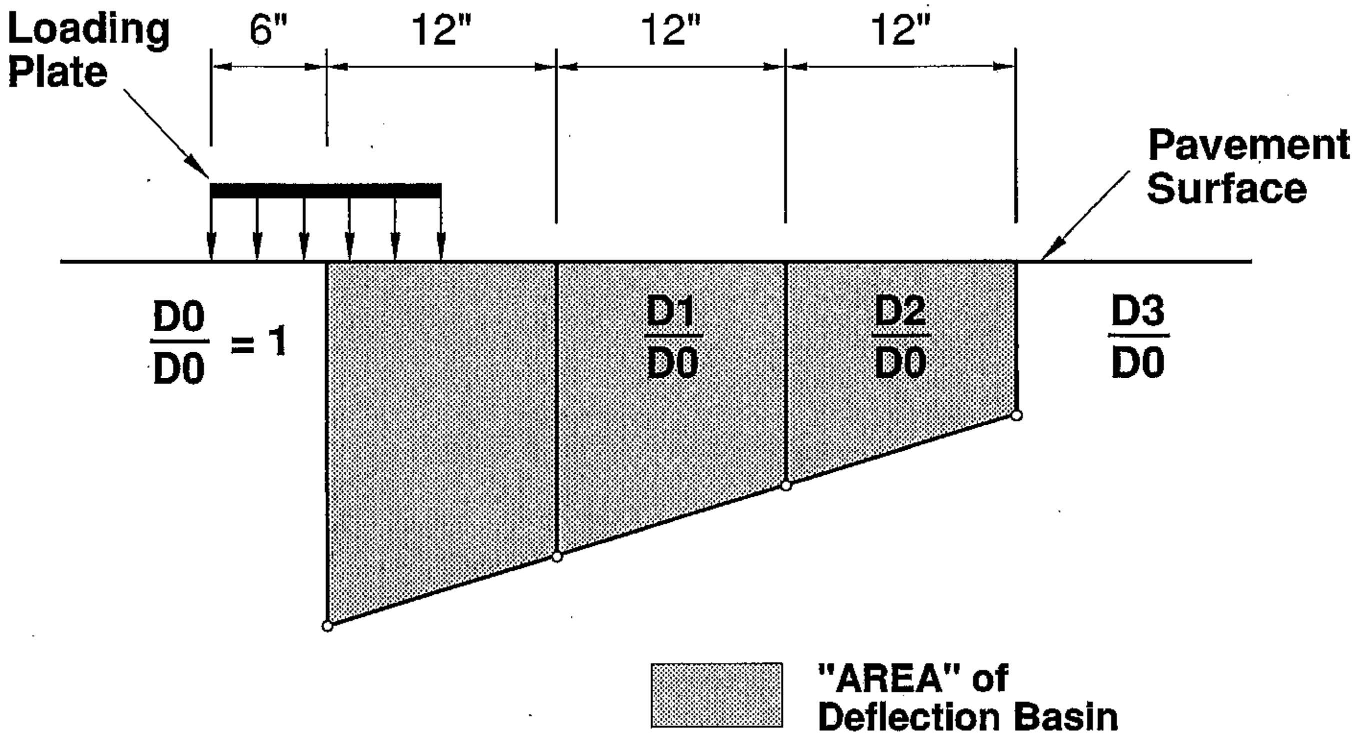


Figure 15. FWD Testing Pattern



$$\text{AREA (inches)} = 6\left(1 + 2\frac{D1}{D0} + 2\frac{D2}{D0} + \frac{D3}{D0}\right)$$

Figure 16. FWD Deflection Basin Area

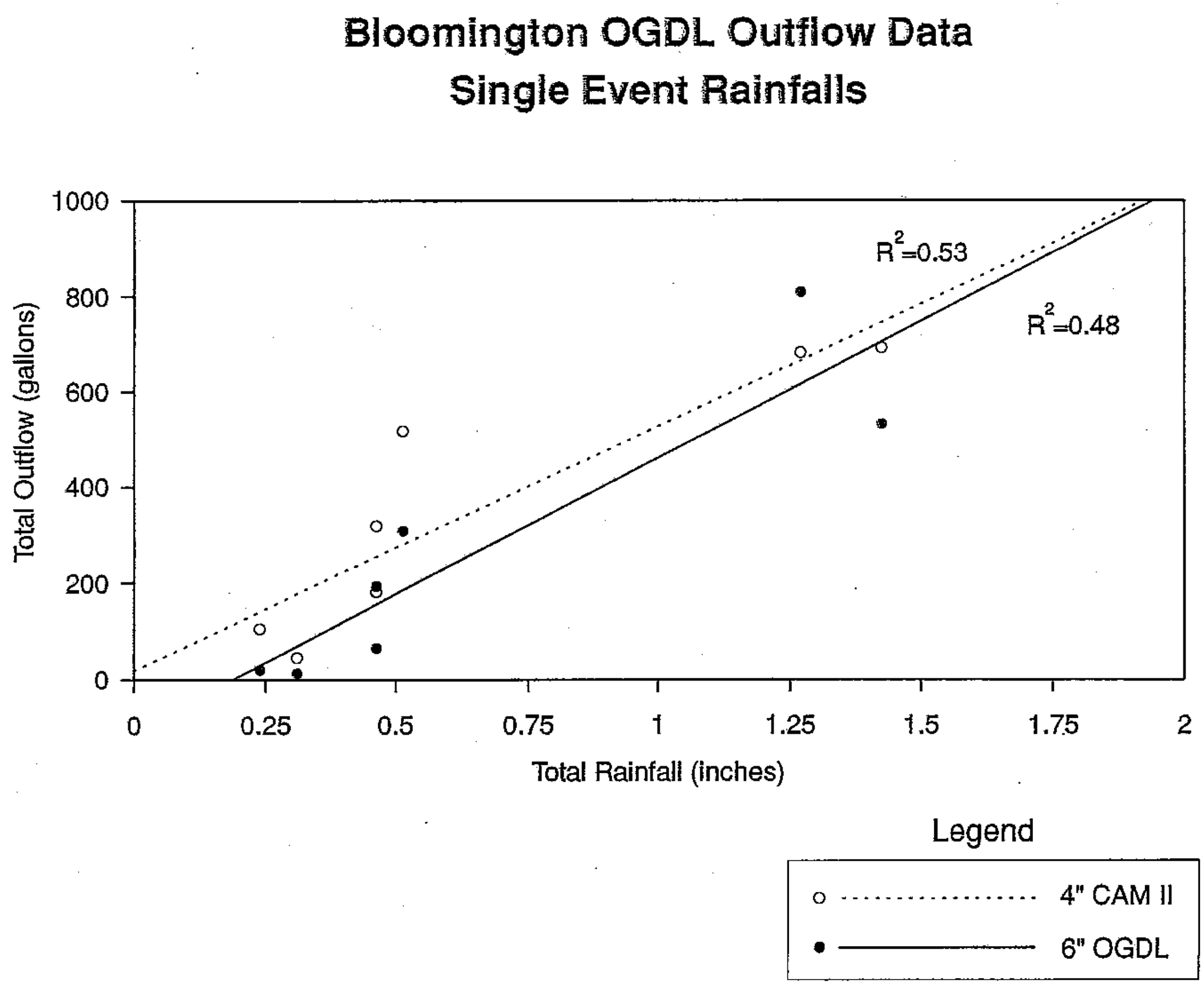


Figure 17. Bloomington Test Section Outflow Data

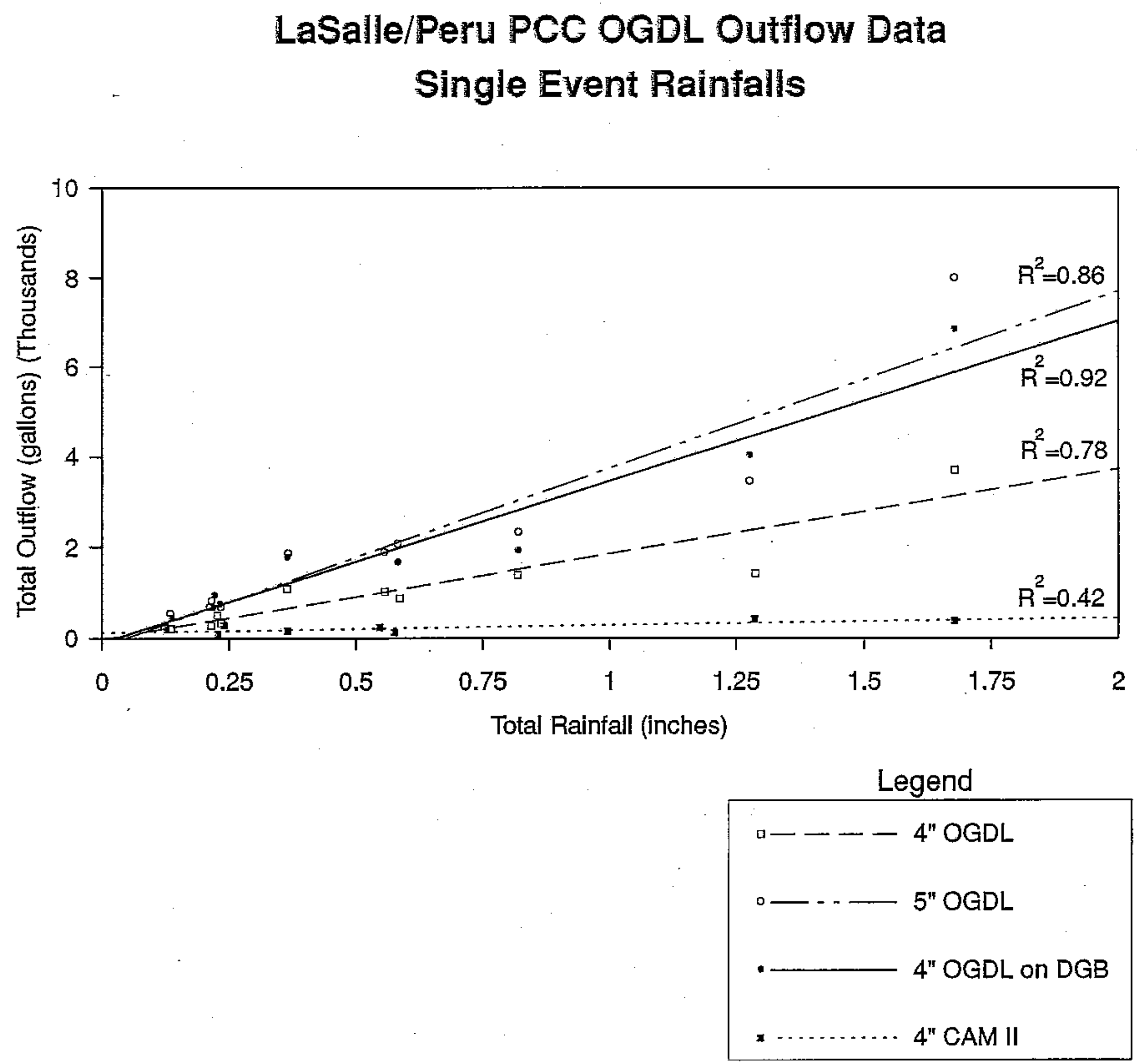


Figure 18. LaSalle/Peru PCC Outflow Data

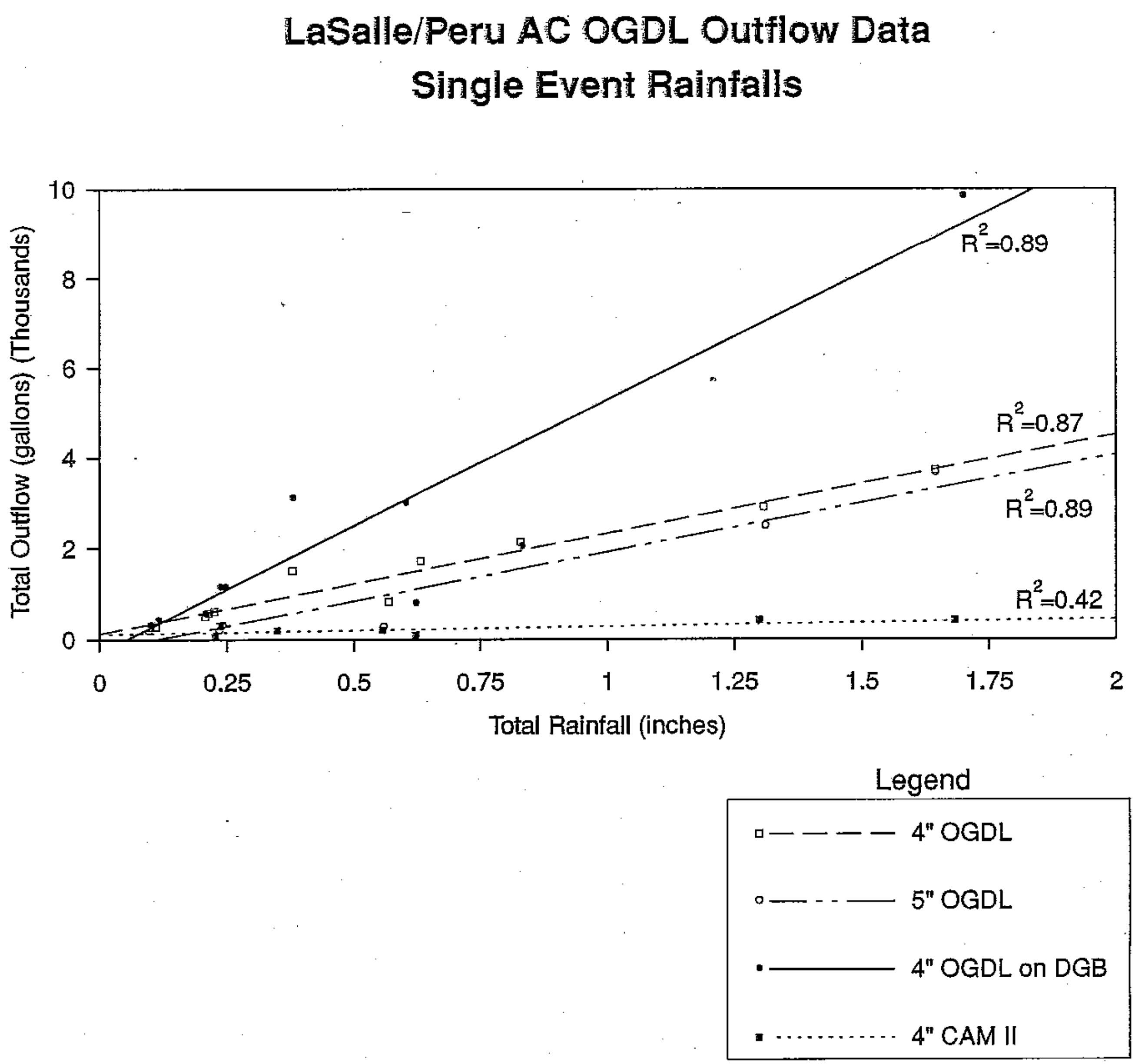


Figure 19. LaSalle/Peru AC Outflow Data

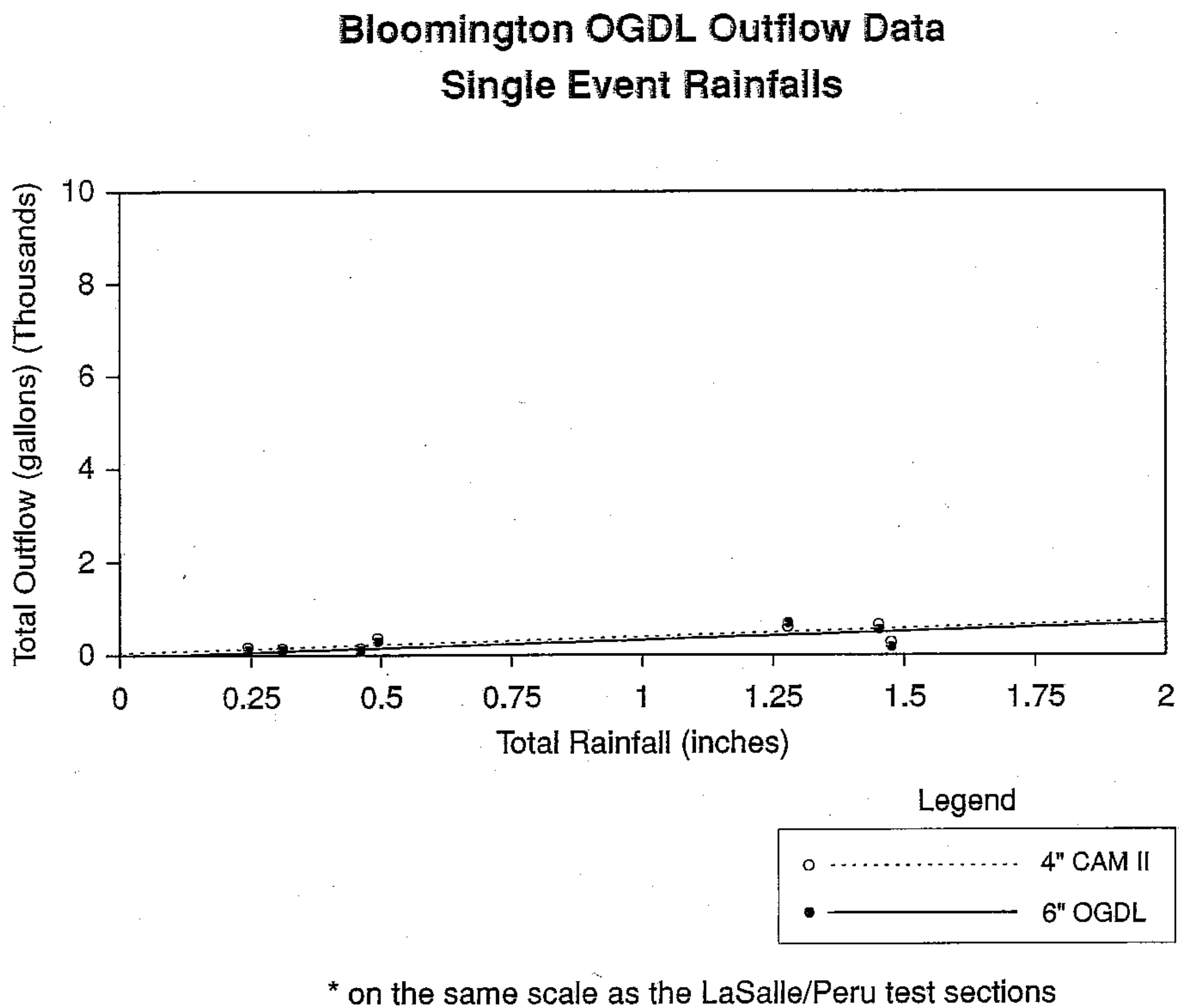


Figure 20. Bloomington Outflow Data On LaSalle/Peru Scale

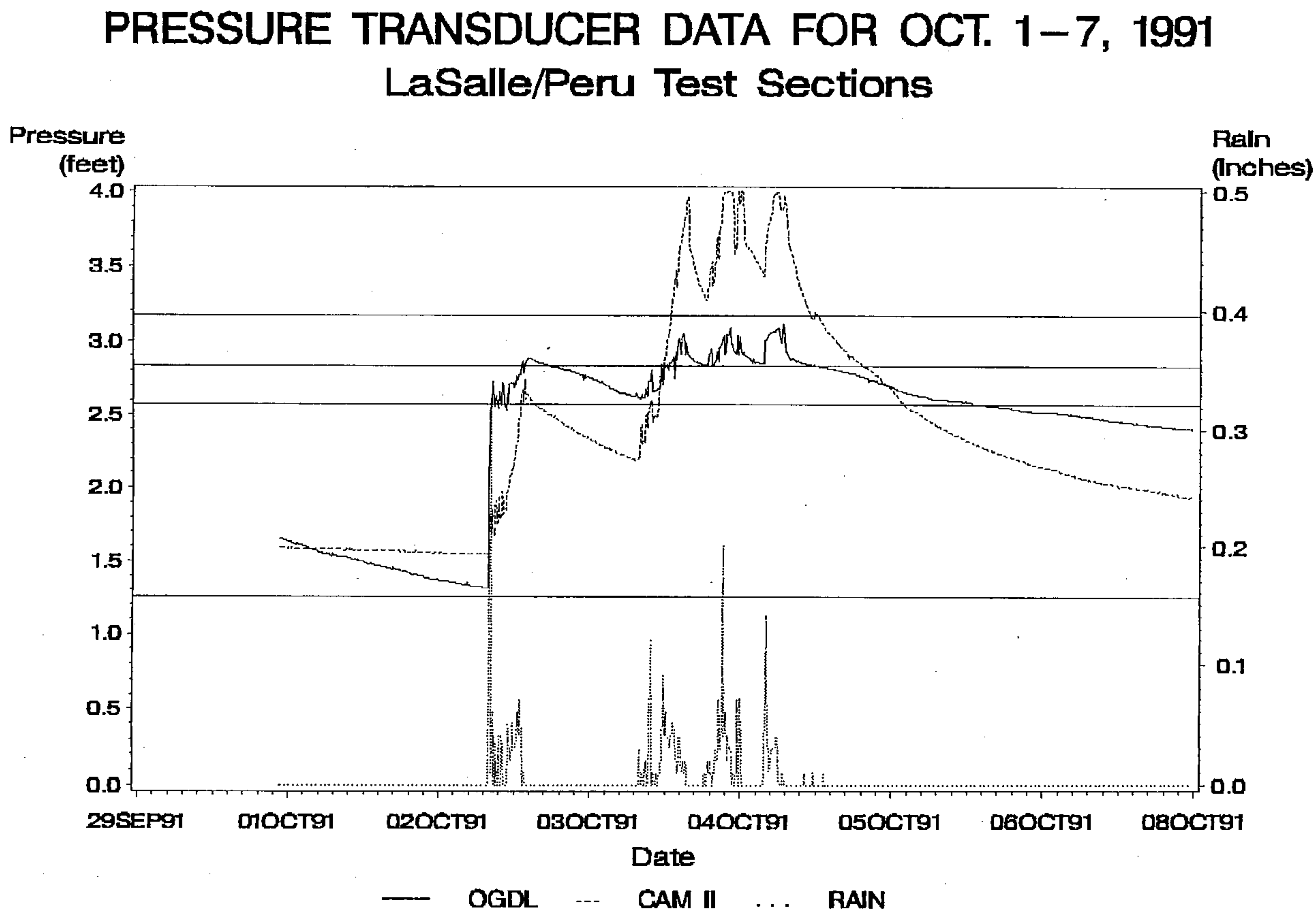


Figure 21. Pressure Transducer Data For October 1-7, 1991

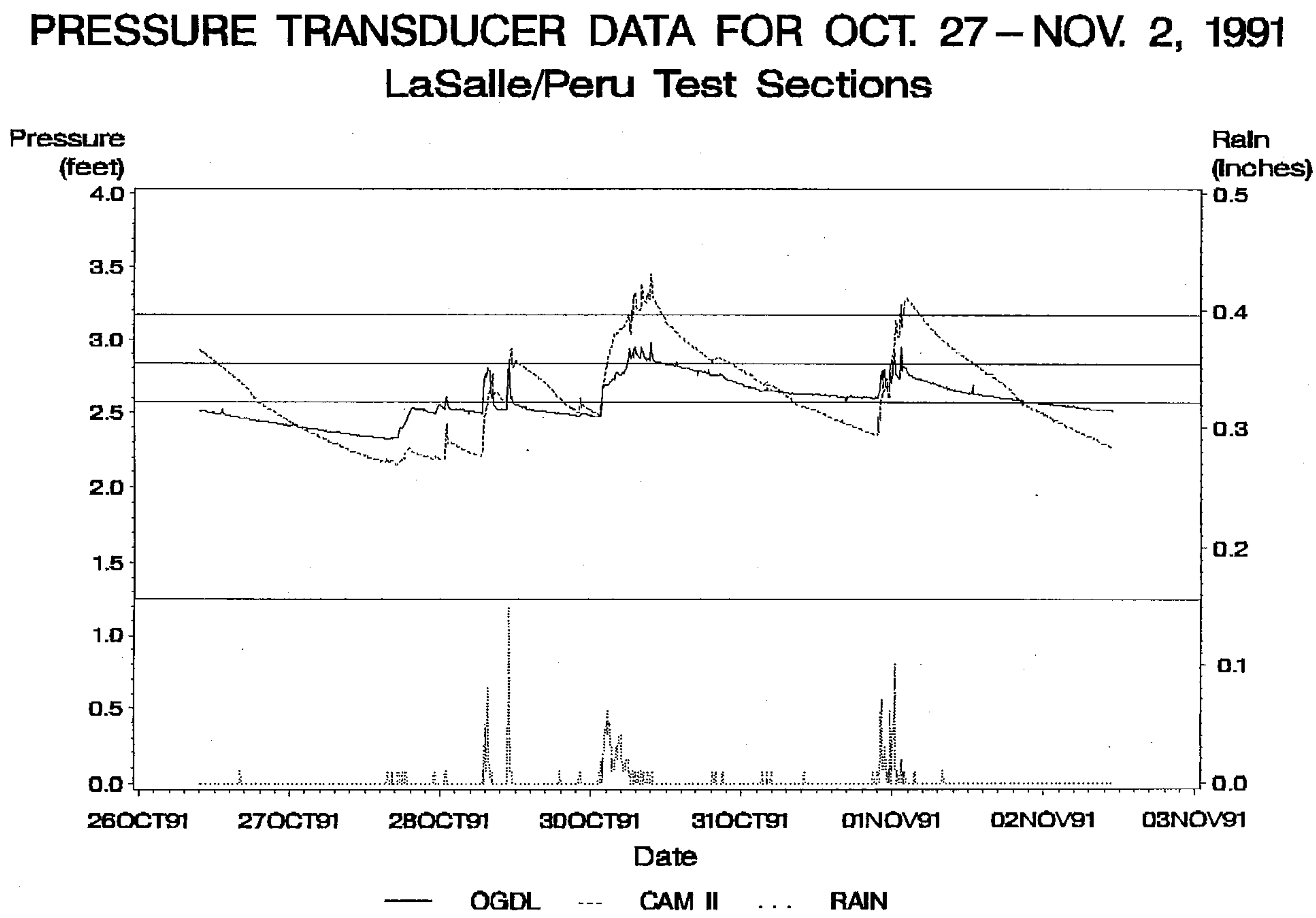


Figure 22. Pressure Transducer Data for October 27 - November 2, 1991

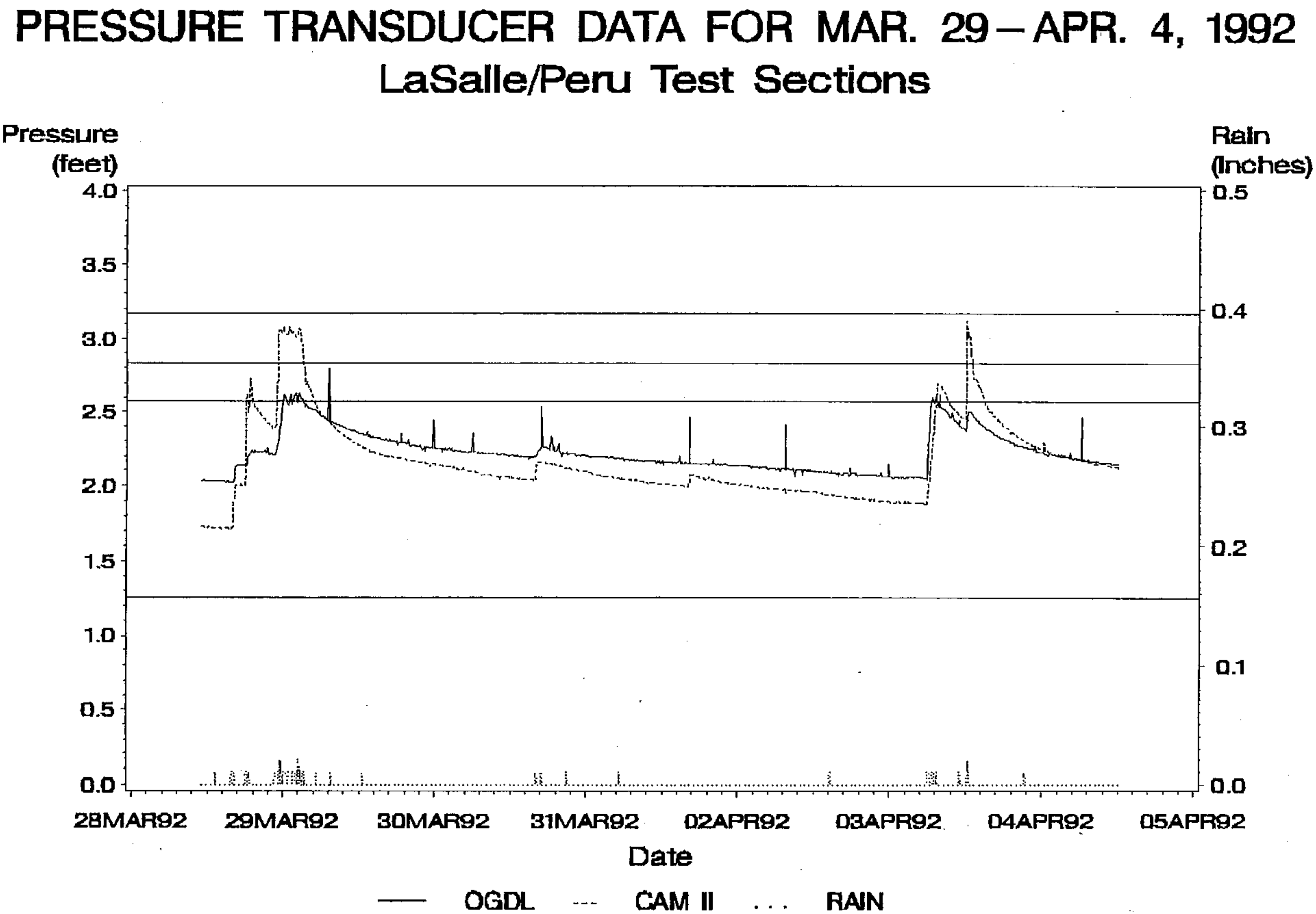


Figure 23. Pressure Transducer Data for March 29 - April 4, 1992

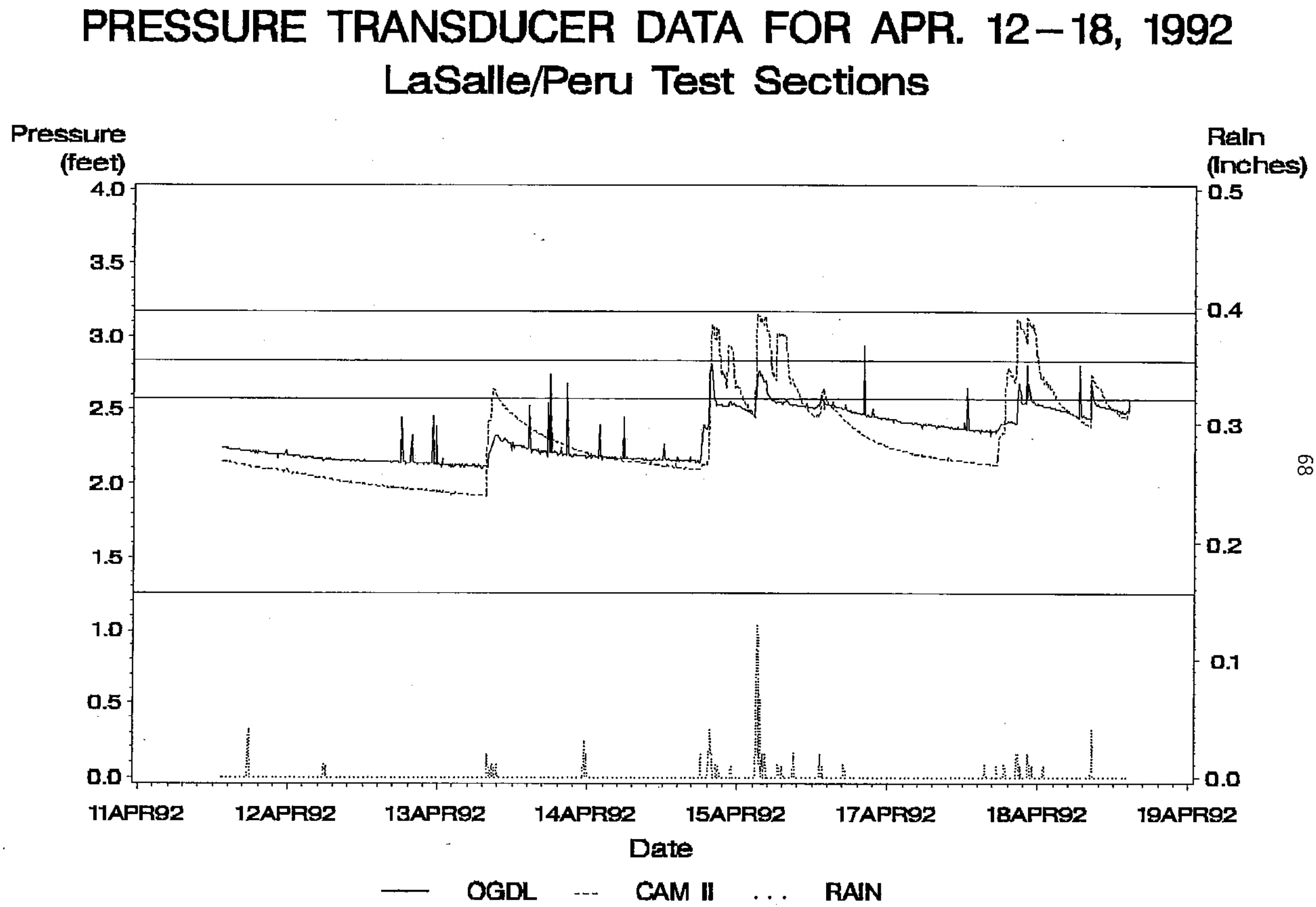


Figure 24. Pressure Transducer Data For April 12 - 18, 1992

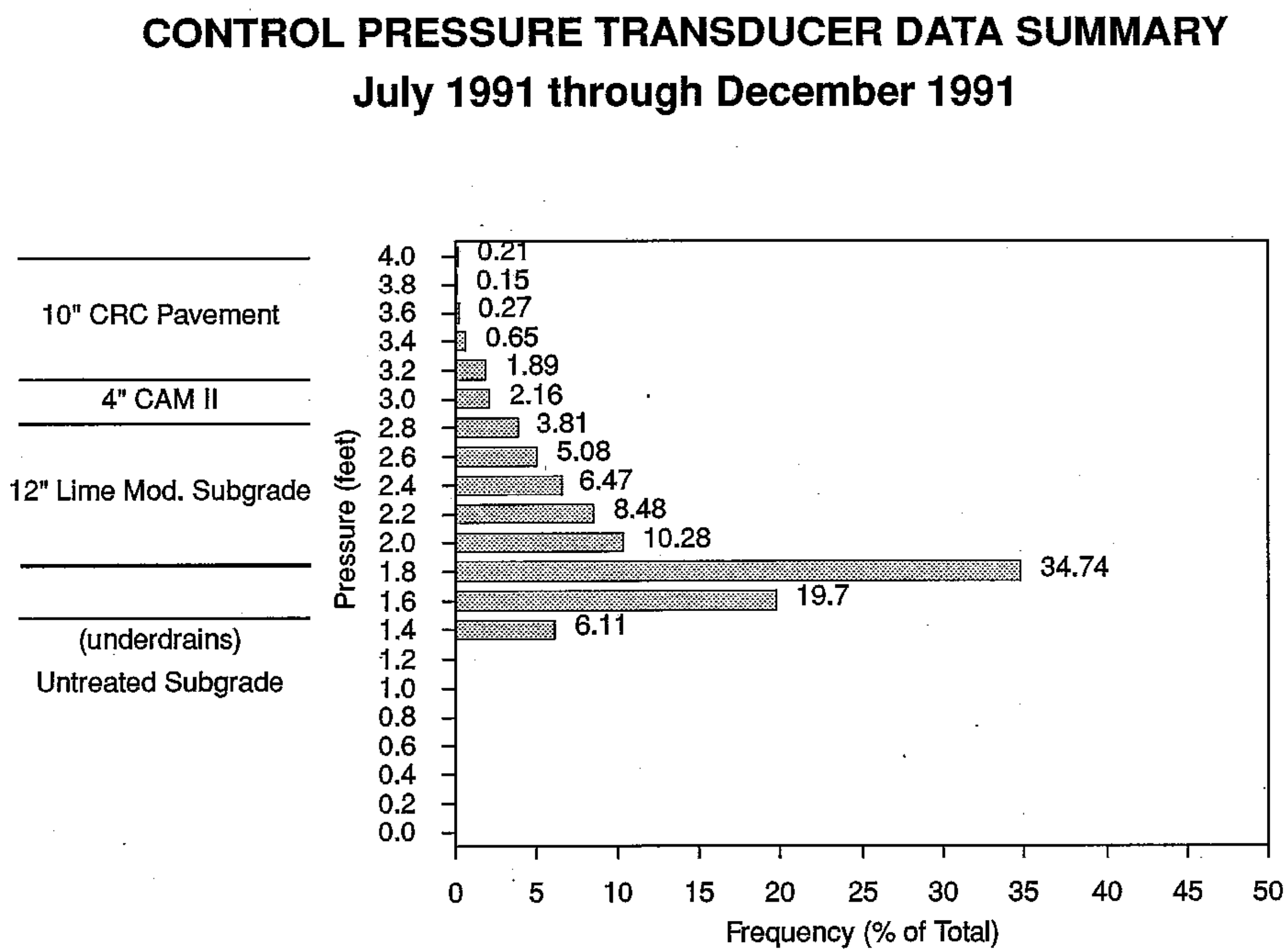


Figure 25. 1991 Control Section Pressure Transducer Data

CONTROL PRESSURE TRANSDUCER DATA SUMMARY
January 1992 through November 1992

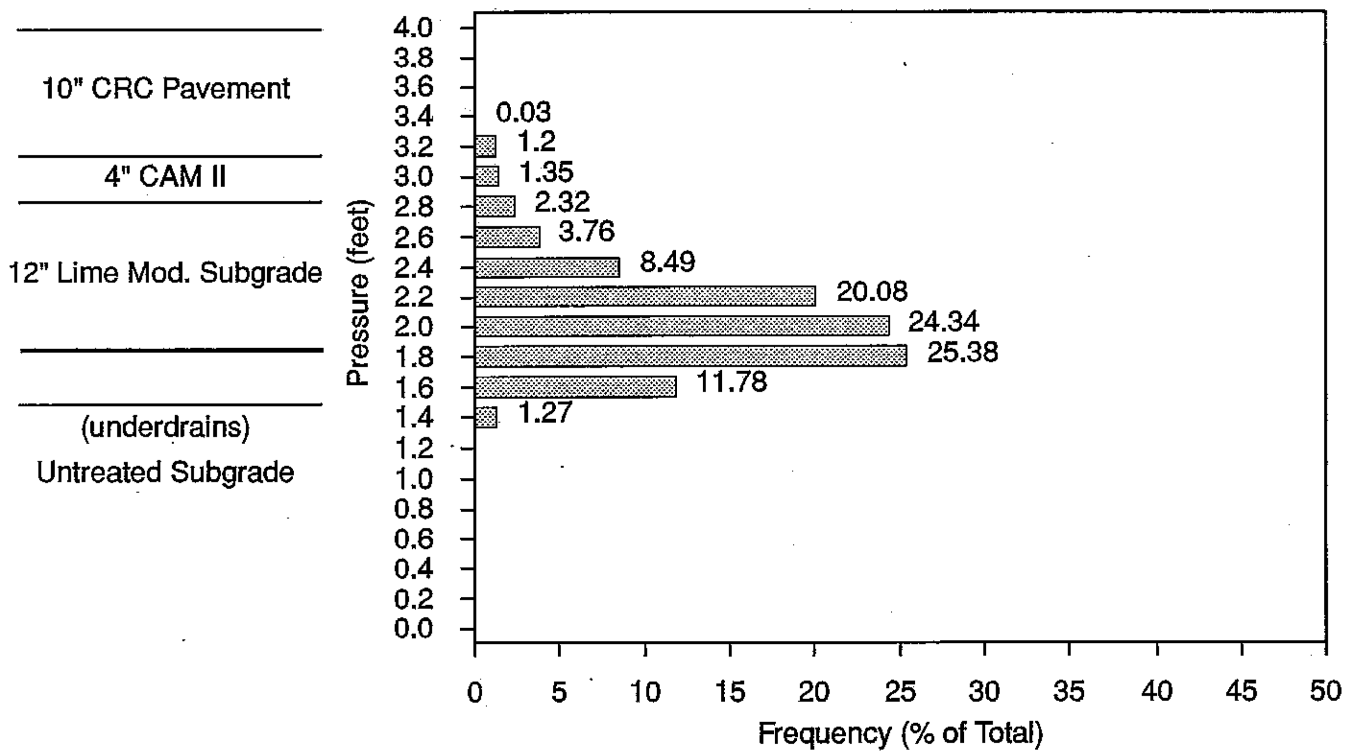


Figure 26. 1992 Control Section Pressure Transducer Data

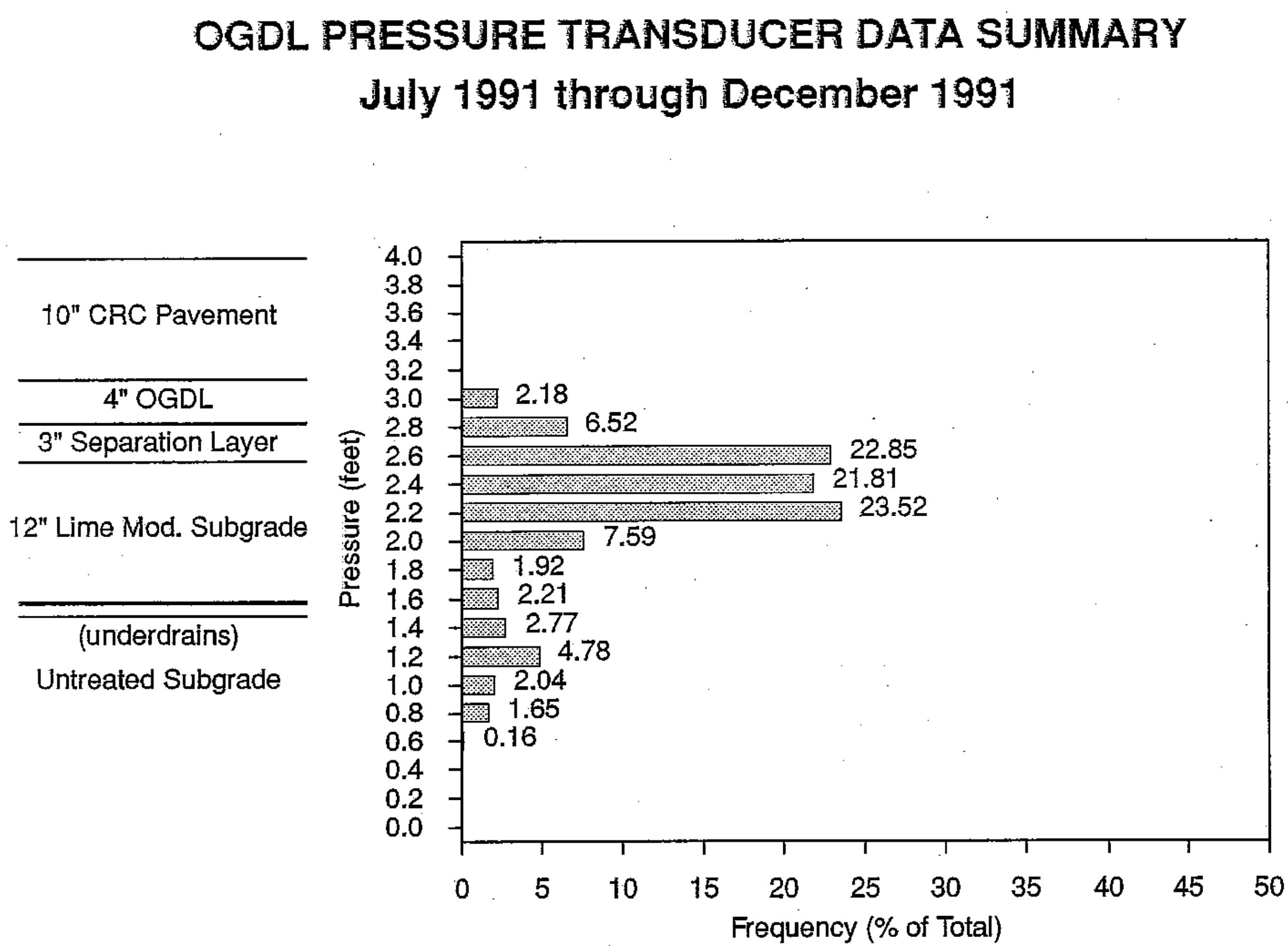


Figure 27. 1991 OGDL Pressure Transducer Data

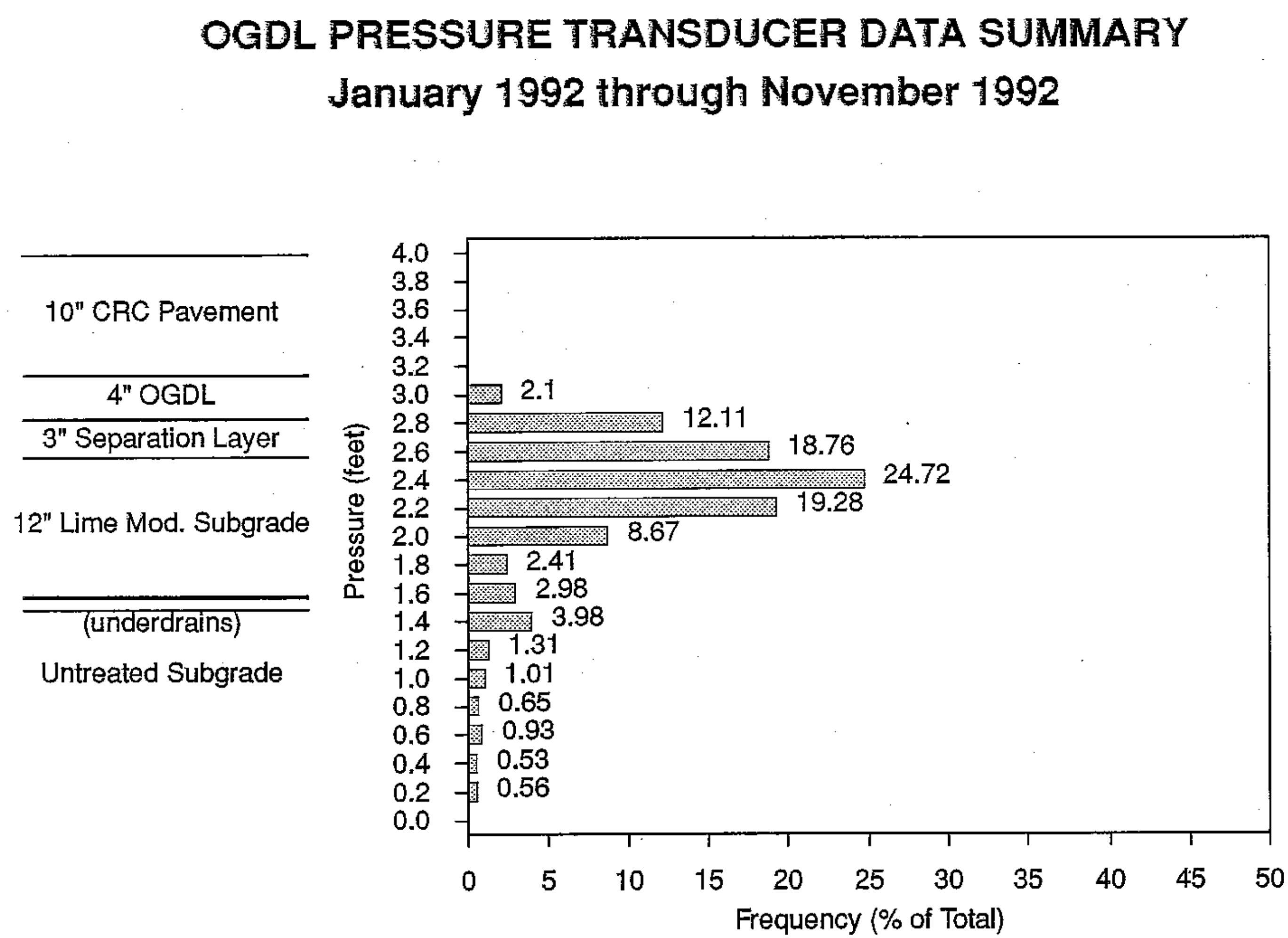


Figure 28. 1992 OGDL Pressure Transducer Data

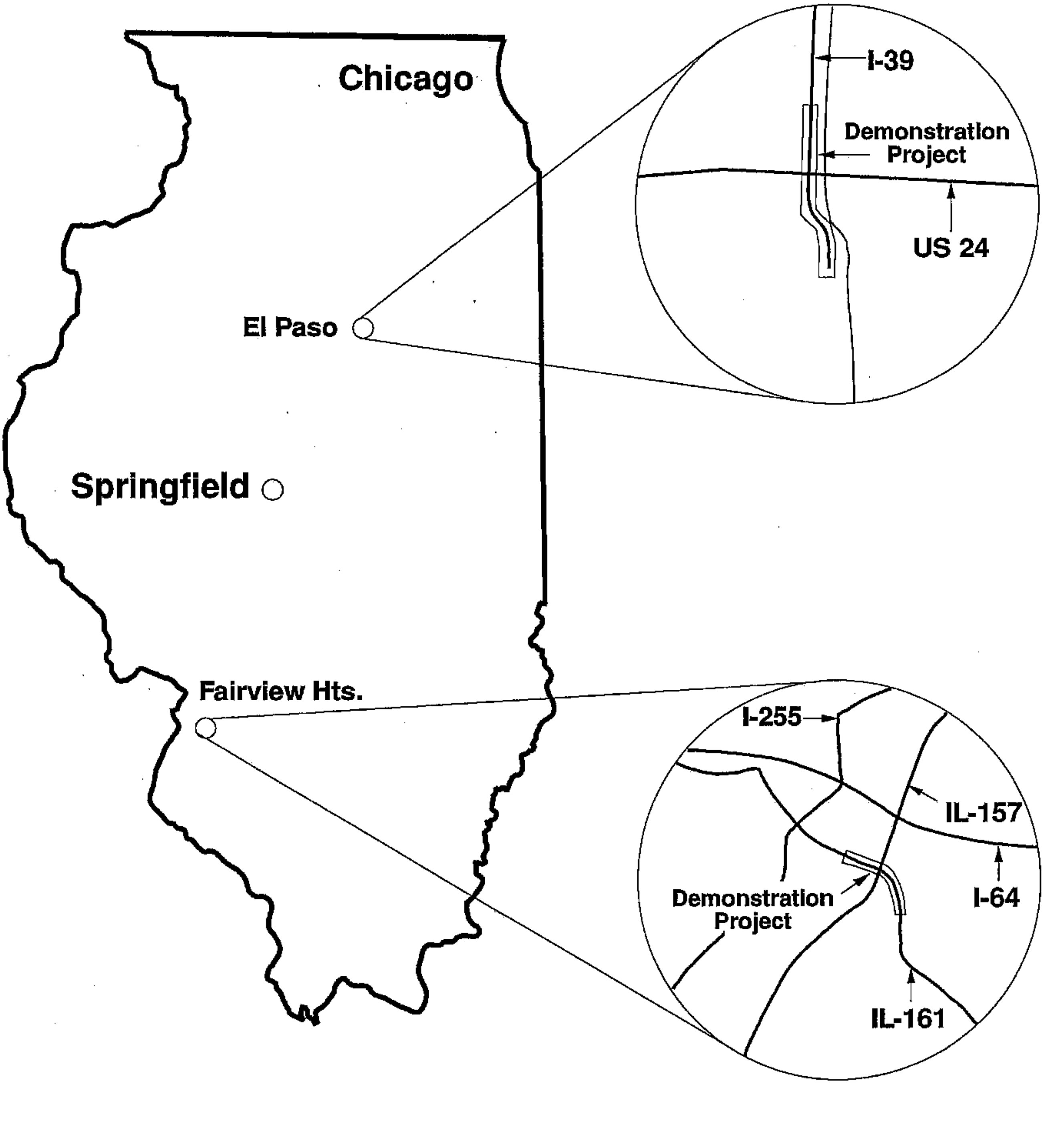


Figure 29. Demonstration Project Locations

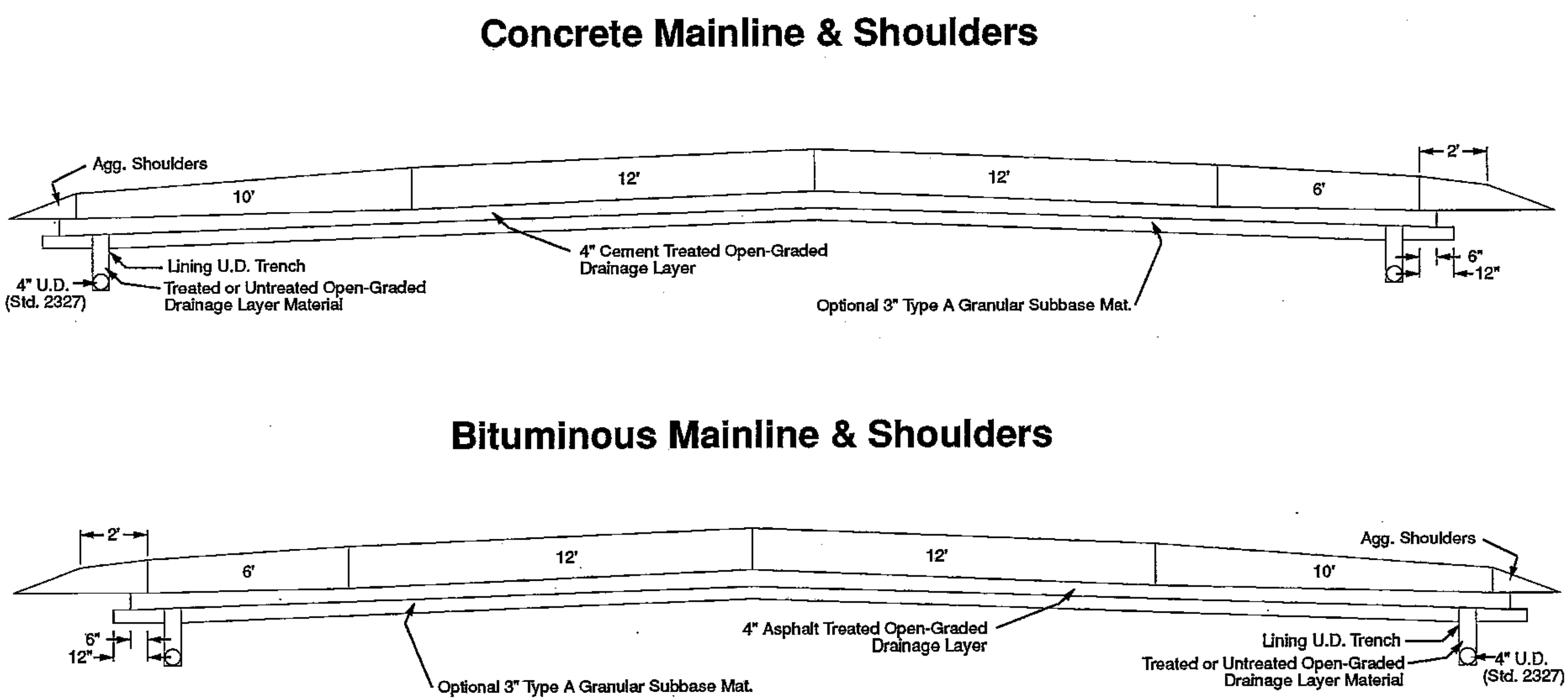


Figure 30. Typical OGDL Cross Sections

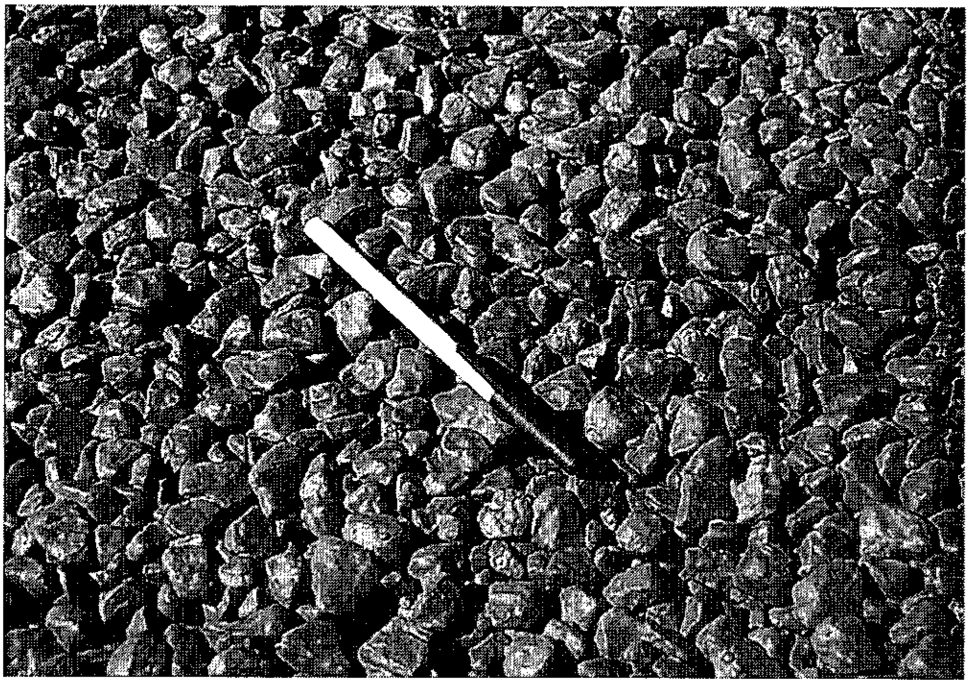


Figure 31. El Paso demonstration project mix.

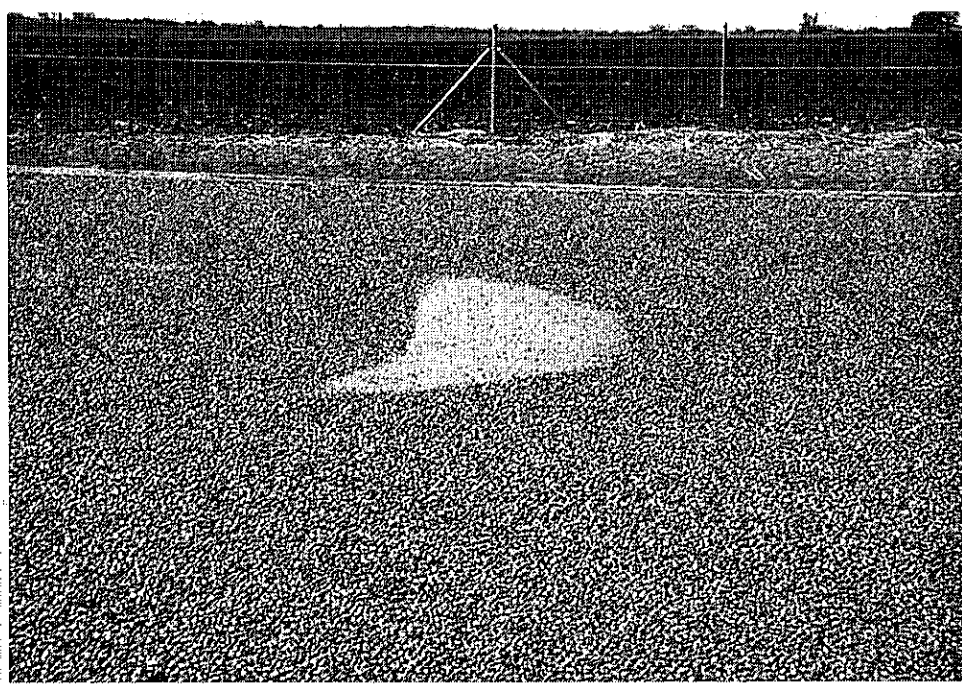


Figure 32. "Wet Spot" due to stockpile moisture.

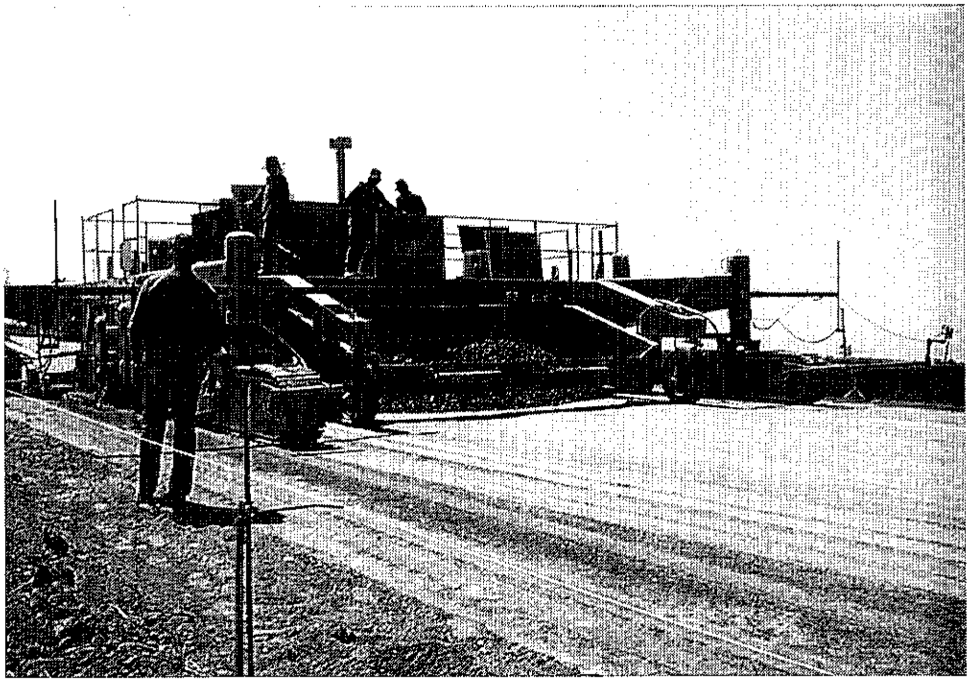


Figure 33. CMI autograde with spreader box.

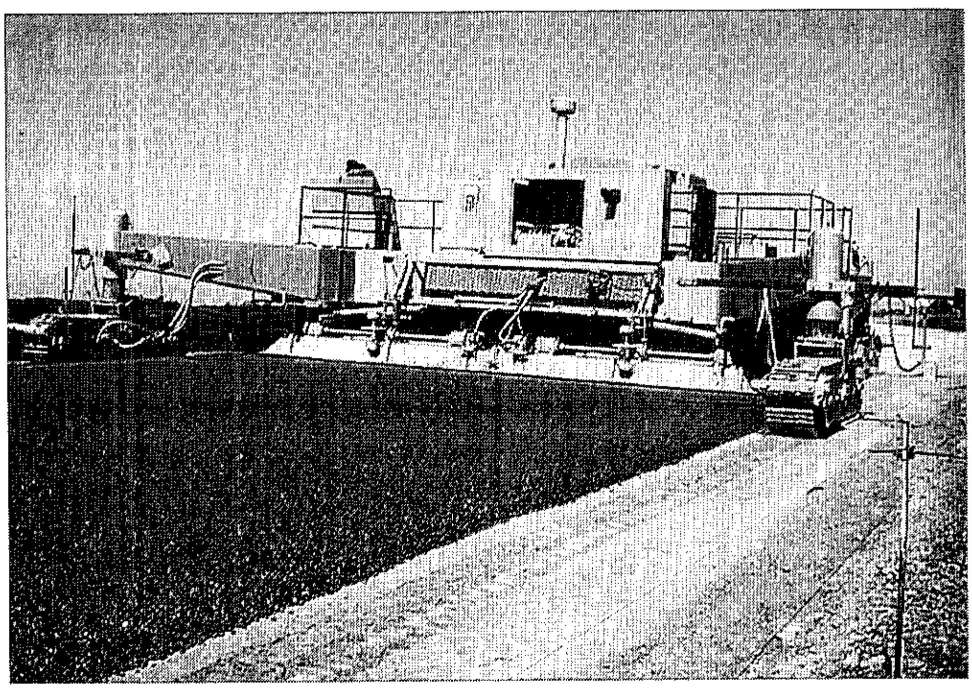


Figure 34. Hydraulic pans used to consolidate the drainage layer.

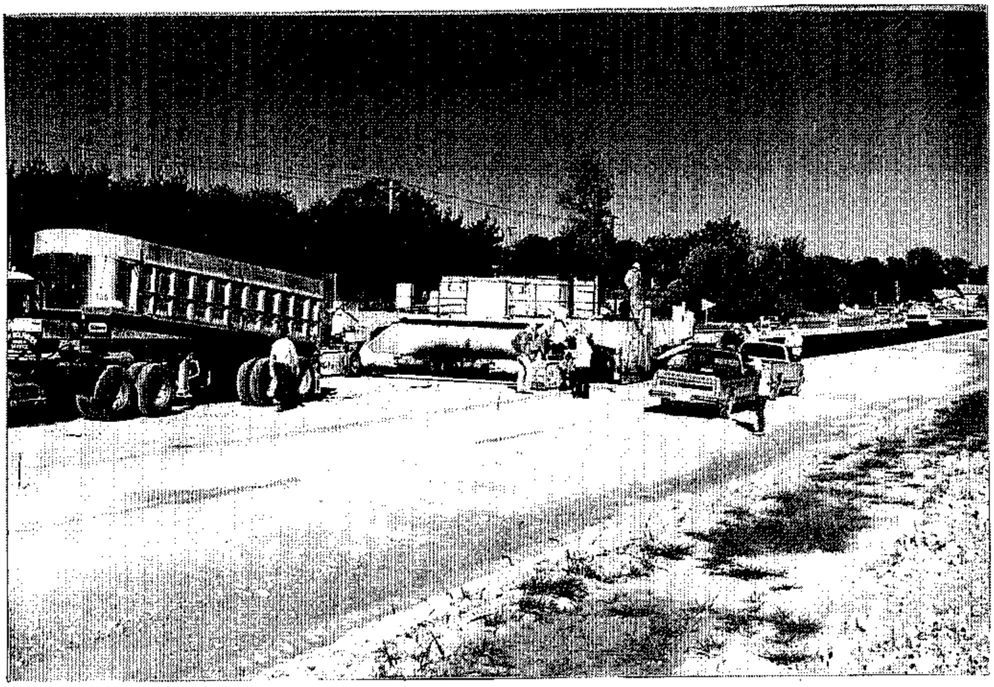


Figure 35. Modified autograde used to place the Belleville demonstration project drainage layer.

Figure 36. Asphalt treated drainage layer after placement.

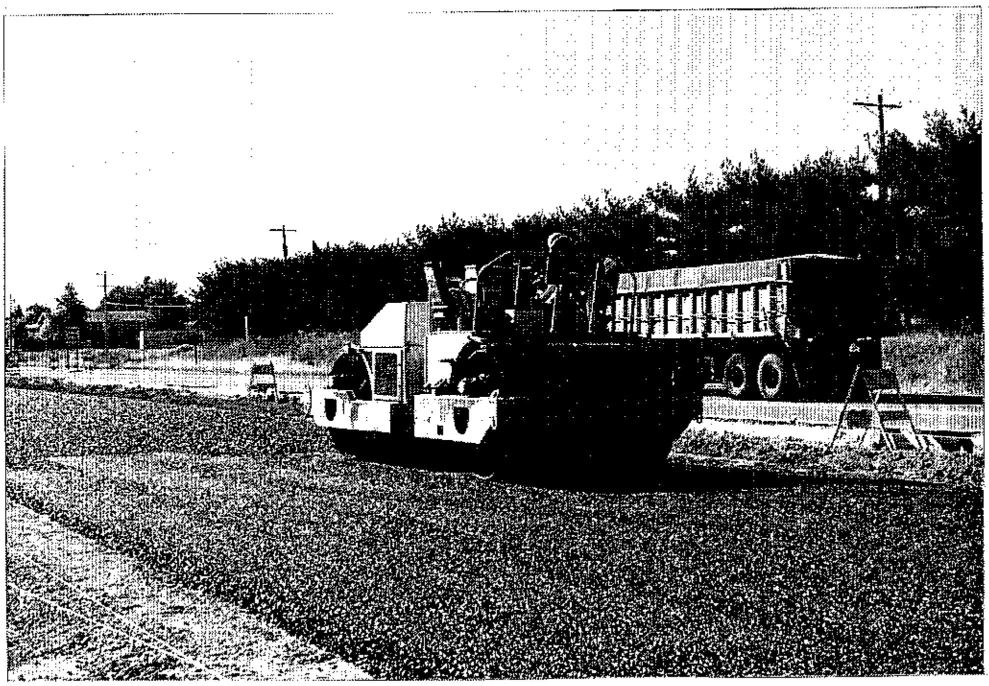


Figure 37. Consolidation of the asphalt treated drainage layer.

Shoulder Detail For P.C.C. Pavements With Open-Graded Drainage Layers

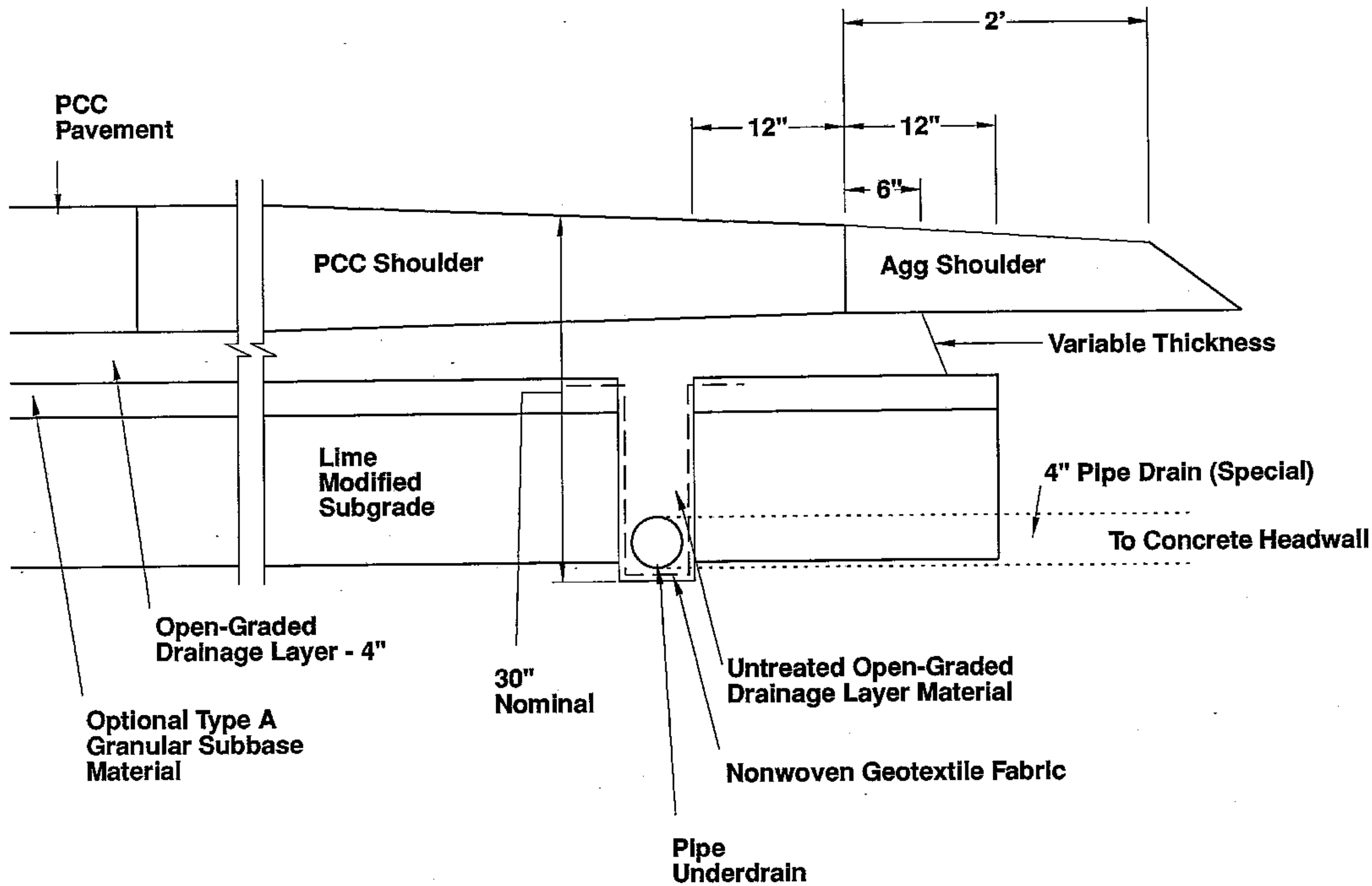


Figure 38. PCC Shoulder/Detail for Drainage Layers

Shoulder Detail For Full-Depth Bituminous With Open-Graded Drainage Layers

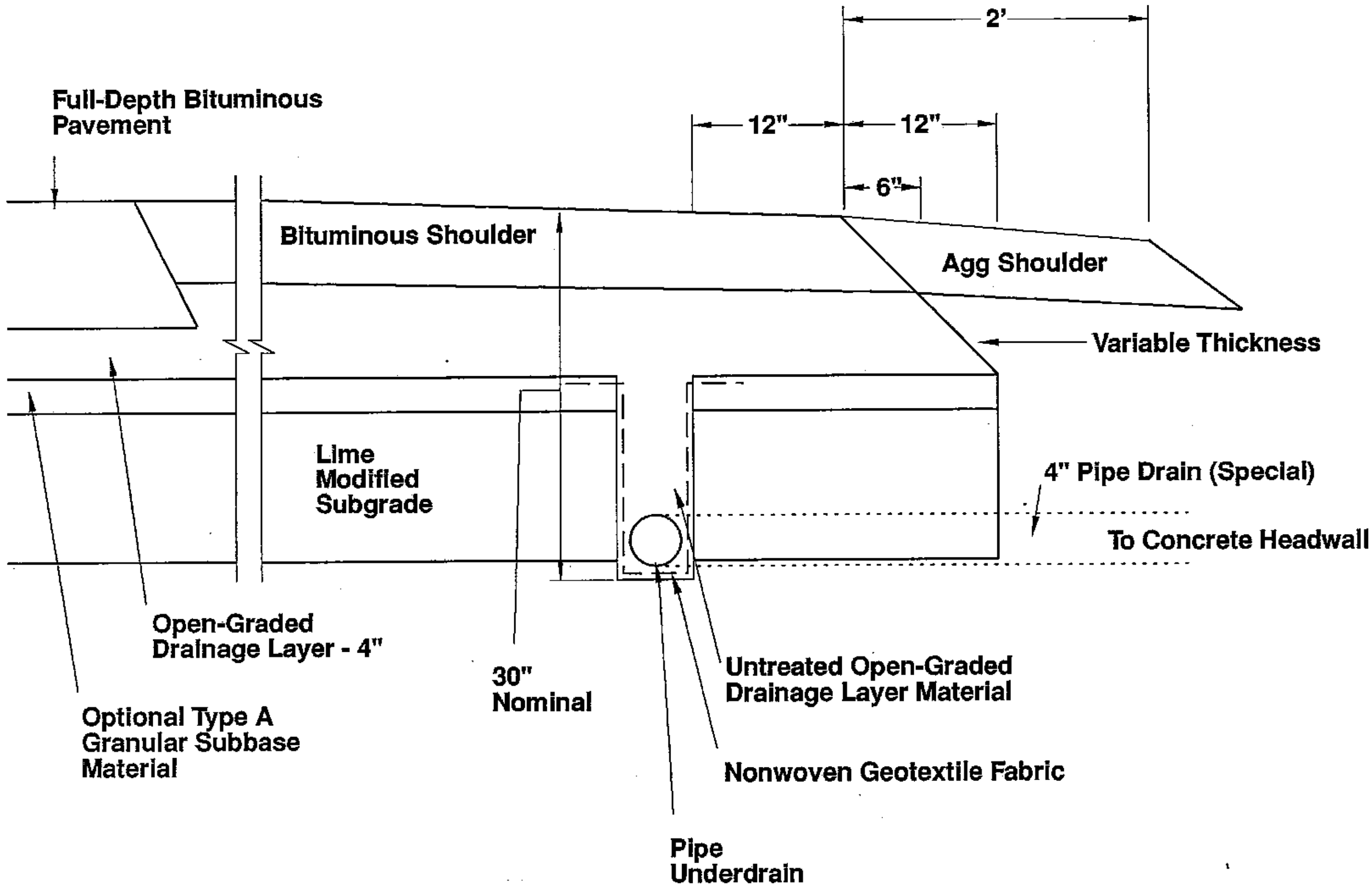


Figure 39. Full-Depth AC Shoulder Detail for Drainage Layers

Appendix

State of Illinois
Department of Transportation

SPECIAL PROVISIONS FOR OPEN-GRADED DRAINAGE LAYER

Effective: March 1, 1993

I. Description:

This work shall consist of constructing a portland cement or asphalt cement treated open-graded drainage layer on a prepared surface to the lines, grades, thicknesses, and cross-sections as shown on the plans. When a type of treatment is not specified, the Contractor shall have the option of using cement or asphalt.

II. Materials:

Materials shall also meet the requirements of the following Articles of Section 700 of the Standard Specifications:

Item	Article/Section
a) Portland Cement	701 1/
b) Water	702 2/
c) Coarse Aggregate	704.01 3/
d) Bituminous Materials	713. 4/

Note 1/ Portland cement shall be Type I or Type II. Cement content shall be no less than 120 Kg./m^3 (200 lbs./cu. yd.) and no more than 165 Kg./m^3 (280 lbs./cu. yd.). Replacement of the cement with a pozzolan will not be permitted.

Note 2/ The water-cement ratio shall be approximately 0.50, and will be adjusted as required by the Engineer to insure aggregate bonding when the mixture is placed and compacted.

Note 3/ The Coarse Aggregate shall be A Quality crushed stone or crushed gravel, and the gradation shall be either CA-7 or CA-11. Blending of the aggregate will not be permitted.

Note 4/ The asphalt cement content shall be 2-3% of dry aggregate weight, with the exact amount determined by the Engineer to insure aggregate bonding when the mixture is placed and compacted. The asphalt cement grade shall be AC-20.

III. Equipment:

The equipment shall meet the requirements of the following Articles of Section 800 of the Standard Specifications:

Item		Article
a)	Water Supply Equipment	803.10
b)	Batching and Weighing Equipment	803.02, 803.03
c)	Concrete Mixer	803.01
d)	Mechanical Concrete Spreader	803.11 1/
e)	Steel Wheel Roller	801.01(e)
f)	Hot-Mix Plant	802.01, 802.14 2/
g)	Subgrade Planer	803.07

Note 1/ Only surface pan vibrators shall be used. A belt placer or spreader box will be required.

Note 2/ For bituminous aggregate mixture, a hot-mix plant conforming to Articles 802.01 or 802.14 will be required except that Articles 802.01 (l), (r), and (v) shall not apply.

IV. Construction:

a) General.

The amount of open-graded drainage layer constructed shall be limited to that which can be surfaced during the current construction season. The Contractor shall have at all times enough drainage layer prepared ahead of the paving location such that paving will be a continuous operation.

The drainage layer shall be placed the full-width of the mainline, as shown on the plans. The drainage layer shall be constructed only when the temperature in the shade is at least 5°C (40°F). No mixture shall be placed on a frozen or saturated surface layer.

The drainage layer shall be constructed to the nominal thickness shown on the plans. Determination for the drainage layer thickness will be based on thickness measurements, taken at either cored points or at the edge of the drainage layer as determined by the Engineer. When the constructed thickness is more or less than 15 mm (0.5 inch) of the nominal thickness, correct thickness will be re-established by the Contractor by removing and replacing with new drainage layer mix at no additional cost.

Care shall be exercised to prevent contamination of the drainage layer. Drainage layer which, in the opinion of the Engineer, has been contaminated shall be removed and replaced with like material by the Contractor at his/her expense. Any damage to the drainage layer shall be repaired promptly by the Contractor at his/her expense and as directed by the Engineer.

The drainage layer shall not be used as a haul road. No traffic or Contractor's equipment will be permitted on the drainage layer except for that paving equipment required to place the subsequent layer of pavement. Hauling on the drainage layer will not be permitted. Trucks will be permitted on the drainage layer only to deliver materials to the paver unless otherwise noted herein. Trucks will be required to vary their access points to the drainage layer. If at any time the trucks create deformations greater than 5 mm (0.25 inch) or cracks in the drainage layer, the trucks delivering materials will no longer be permitted on the drainage layer.

The Contractor shall remove and replace at the Contractor's own expense any drainage layer which is unsatisfactory due to rain, freezing, or other climatic conditions; damaged by traffic; or which is unsatisfactory due to failure to comply with any of the requirements specified herein.

b) Portland Cement Treated Open-Graded Drainage Layer

The drainage layer shall be handled, mixed, and placed in accordance with Articles 408.07, 408.08, 408.09, and 408.12(e) of the Standard Specifications. A mechanical concrete spreader shall be used to place the drainage layer. When a slipform paver is used for placing the pavement, the drainage layer shall be constructed to a width 300 mm (12 inches) wider than the width outside-to-outside of the slipform paver's tracks.

Paving equipment shall not be allowed on the drainage layer for at least three days after placement.

When the open-graded drainage layer extending beyond the edge of pavement has been contaminated as determined by the Engineer, the contaminated portions shall be removed without contaminating the remaining open-graded drainage layer.

c) Asphalt Cement Treated Open-Graded Drainage Layer.

The drainage layer mixture shall be prepared in accordance with Article 406.12 of the Standard Specifications except that (a), (b), (c), and (d) shall not apply. The mix temperatures shall not be more than 150°C (300°F) or less than 115°C (240°F) at the mixing plant, and no dry mix time will be required.

The drainage layer mixture shall be transported in accordance with Article 406.13 of the Standard Specifications except the minimum temperature behind the paver screed shall be 95°C (200°F).

The mixture shall be placed in one lift with a subgrade planer. The drainage layer shall be placed at least 300 mm (12 inches) wider than the first lift of binder on either side when placed under a full-depth asphalt concrete pavement.

The drainage layer shall be rolled and compacted thoroughly and uniformly with 2 steel-wheeled, 2-axle tandem rollers. The break-down roller processing an operating weight of not more than 2.23 kg/mm (125 lb/inch) of roller width. The finish roller producing an operating weight of 4.46 kg/mm (250 lb/inch) to 7.14 kg/mm (400 lbs/inch) of roller width.

The break-down roller shall not start rolling until the drainage layer temperature is less than 95°C (200°F) and must be completed before the temperature of the drainage layer drops below 65°C (150°F). The finish roller shall not begin rolling until the temperature of the drainage layer is less than 65°C (150°F) and shall be completed before the temperature of the drainage layer is 40°C (100°F). A maximum of 2 passes per roller will be required.

The drainage layer shall not be cooled to the specified compaction temperatures with water. Paving equipment will not be allowed on the drainage layer for at least 24 hours after placement.

When the open-graded drainage layer extending beyond the 1:1 wedge for full-depth asphalt concrete has been contaminated as determined by the Engineer, the contaminated portions shall be removed without contaminating the remaining open-graded drainage layer.

V. Method of Measurement:

(a) Contract Quantities. When the work is constructed essentially to the lines, grades, or dimensions shown on the plans, and the

Contractor and the Engineer have agreed in writing that the plan quantities are accurate, no further measurement will be required and payment will be made for the quantities shown in the contract for the various items involved, except that if errors are discovered after the work has been started, appropriate adjustments will be made.

When the plans have been altered or when disagreement exists between the Contractor and the Engineer as to the accuracy of the plan quantities either party shall, before any work is started which would affect the measurement, have the right to request in writing and thereby cause the quantities involved to be measured as herein specified.

(b) Measured Quantities. Open-graded drainage layer will be measured in-place and the area computed in square meters (square yards). The width for measurement will be the dimensions as shown on the plans.

VI. Basis of Payment:

This work will be paid for at the contract unit price per square meter (square yard) for PORTLAND CEMENT TREATED OPEN-GRADED DRAINAGE LAYER, ASPHALT CEMENT TREATED OPEN-GRADED DRAINAGE LAYER OR OPEN-GRADED DRAINAGE LAYER (OPTION).

State of Illinois
Department of Transportation

SPECIAL PROVISION FOR PIPE DRAINS AND PIPE UNDERDRAINS FOR OPEN-GRADED DRAINAGE LAYERS

Effective: March 1, 1993

Description:

This work shall consist of furnishing and constructing pipe drains and pipe underdrains of the required inside diameter, with the necessary fittings and open-graded materials as described herein.

Materials:

Pipe underdrain material shall meet the requirements of Article 709.19 or 709.24 of the Standard Specifications or 709.27 included in the Special Provision for Corrugated Polyethylene Tubing and Piping included elsewhere herein.

Pipe drain material shall meet the requirements of Article 709.20 or 709.25 of the Standard Specifications or 709.28 included in the Special Provision for Corrugated Polyethylene Tubing and Piping included elsewhere herein.

Construction:

(a) Pipe Underdrain Installation. Trenches shall be excavated to the dimensions and grade as shown on the plans and as directed by the Engineer. The excavated trench shall be lined with a geotechnical fabric as specified in the Special Provision for Nonwoven Geotechnical Fabric Lining for Open-Graded Drainage Layer Underdrain Trenches included elsewhere herein and shall be placed as shown on the plans.

The backfill material shall be untreated open-graded drainage layer material meeting the requirements as specified in the Special Provision for Open-Graded Drainage Layers included elsewhere herein.

After the pipe installation has been inspected and approved, the trench shall be backfilled with untreated open-graded drainage layer material to a height of 300 mm (12 inches) above the top of the pipe and shall be compacted using a vibratory roller meeting requirements 801.01(g) to the statisfaction of the Engineer. Care shall be taken not to displace the pipe. The remainder of the untreated open-graded drainage layer material shall then be placed and compacted to the required height.

No equipment shall be operated directly upon the completed pipe installation for longitudinal underdrains.

(b) Pipe Drain Installation. The pipe drain shall be installed in accordance with Article 607.03(b) of the Standard Specifications except that untreated open-graded drainage layer material shall be used as backfill from the pipe underdrain trench to the outside edge of the shoulder.

Method of Measurement:

Pipe drains and pipe underdrains will be measured for payment in lineal feet in-place.

Basis of Payment:

(a) Pipe Underdrains. This work will be paid for at the contract unit price per lineal foot for PIPE UNDERDRAINS 100 mm (4-inch) (modified). This price shall include the cost of all work described herein including all pipe fittings, all excavation except in rock, and the disposal of all surplus materials excavated from the trenches.

Removal and replacement of unstable or unsuitable material will be paid for as extra work in accordance with Article 109.04, unless the contract contains unit prices for the work included. Payment will be made only when such work is authorized in writing by the Engineer, and only for work within the dimensional limitations which the Engineer establishes.

Backfill material will not be measured and paid for separately but will be included in the cost of the pipes.

(b) Pipe Drains. This work will be paid for at the contract unit price per lineal foot for PIPE DRAINS 100 mm (4-inches), which the price shall be payment in full for all work described herein, including all excavation except that required for the removal of unstable or unsuitable material or rock.

Inlets, headwalls, and aprons, when required, will be paid for separately as provided in the respective items of work.

Backfill material will not be measured and paid for separately but will be included in the cost of the pipes.

State of Illinois
Department of Transportation

SPECIAL PROVISIONS
FOR
NONWOVEN GEOTECHNICAL FABRIC LINING
FOR OPEN GRADED DRAINAGE LAYER
UNDERDRAIN TRENCHES

Effective: March 1, 1993

Description:

This work shall consist of furnishing all materials, equipment, and labor and performance of all required operations for the installation of geotechnical fabric in lining trenches.

Materials:

Nonwoven Fabric. The filaments for nonwoven fabric shall be polyester or polypropylene. The filaments shall be dimensionally stable (i.e., filaments shall maintain their relative position with respect to each other) and resistant to delamination. The filaments shall be free from any chemical treatment or coating that might significantly reduce porosity and permeability. Nonwoven fabric shall be needle punched, heat bonded, resin bonded, or combinations thereof.

PHYSICAL PROPERTIES

Weight (ASTM D 3776)	0.15 Kg./sq. m. (4.0 oz./sq. yd.)
Wet Grab Tensile Strength (ASTM D 4632)	580 N. (130 lbs.)
Grab Elongation at Break (ASTM D 4632)	20 %
Equivalent Opening Size 1/	70 E05 No.
Mullen Burst Strength (ASTM D 3786)	1.4 M. Pa. (210 psi)
Trapezoidal Tear (ASTM D 4533-85)	180 N. (40 lbs.)
Puncture Strength (ASTM D 4833)	180 N. (40 lbs.)

1/ Manufacturer's certification to meet test requirements.

Handling and Storage:

Nonwoven fabric shall be delivered to the job site in such a manner as to facilitate handling and incorporation into the work without damage. Fabric shall be stored in UV-resistant bags until just prior to installation. In no case shall the fabric be stored or exposed to direct sunlight that might significantly diminish its strength or toughness. Torn, punctured, or contaminated fabric shall not be used.

Construction:

After the trench has been excavated to the required depth, leveled and smoothed as shown on the plans, the fabric shall be loosely rolled out in such a manner that the center of the fabric is at the centerline of the trench.

The fabric shall extend at least 150 mm (6 inches) minimum on either side of the trench. The fabric shall not be stretched so that it will tear when the trench backfill material is placed. When several sections of fabric are used, the fabric shall overlap a minimum of 600 mm (2 feet) to assure continuity of the filter.

Method of Measurement and Payment:

Nonwoven geotechnical fabric will not be measured and paid for separately, but included in the contract unit price for the pipes included elsewhere. All excavation and disposal of surplus material shall be included in the cost of the pipes.

State of Illinois
Department of Transportation

SPECIAL PROVISION FOR SEPARATION LAYER FOR OPEN-GRADED DRAINAGE LAYERS

Effective: March 1, 1993

Description:

This item shall consist of constructing a separation layer on a prepared lime treated subgrade to the lines, grades, thicknesses, and cross-sections as shown on the plans and in accordance with the applicable portions of Section 213 of the Standard Specifications for Type A Granular Subbase except as follows:

Materials:

Coarse aggregate shall be crushed stone or crushed gravel.

Coarse aggregate shall be CA-6 or CA-10.

Blending of aggregate will not be permitted.

The separation layer material shall have a plasticity index of 0-4.

Construction:

The granular material shall be placed and compacted at least 24 hours prior to the placement of pavement or base course.

Article 213.06 shall not apply. The separation layer shall be brought to true shape by means of a subgrade planer immediately prior to depositing material for the open-graded drainage layer.

The contractor shall have at least 250 meters (800 feet) of the separation layer placed ahead of the location at which the open-graded drainage layer is being placed.

Basis of Payment:

This work will be measured and paid for at the contract unit price per square meter (square yard) for SEPARATION LAYER.